MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY

Vol. 118 No. 4

ANNIVERSARY MEETING OF 1958 FEBRUARY 14

Dr W. H. Steavenson, President, in the Chair

The election by the Council of the following Fellows was duly confirmed:—

Norman Edward James Aldous, 52 Longfleet Road, Poole, Dorset (proposed by W. Newsham);

Robert Owen Bishop, University Observatory, Oxford (proposed by H. H. Plaskett);

Nicholas T. Bobrovnikoff, Perkins Observatory, Delaware, Ohio, U.S.A. (proposed by P. C. Keenan);

John Vincent Dobson, 31 St. Oswald's Street, West Hartlepool (proposed by G. Fielder);

Aiden Alexander Rowlands, 33 Arlington Drive, Carshalton, Surrey (proposed by R. H. Garstang);

David Edmund Smith, University College, Durham, (proposed by F. Sheldrake); and

Lionel Allen Cromwell Warner, Avondale College, Auckland, New Zealand (proposed by R. A. McIntosh).

The election by the Council of the following Junior Members was duly confirmed:—

Donald Lynden-Bell, 12 Queen Edith's Way, Cambridge (proposed by L. Mestel); and

Georg Emanuel Morduch, Greenbanks, Marsham Way, Gerrards Cross, Bucks (proposed by G. J. Whitrow).

Eighty-three presents were announced as having been received since the last meeting, including:—

W. Brauch: *Zur Dokumentation und Klassification der Geophysik*, (presented by the author);

C.S.I.R.O. Radiophysics Laboratory: *Symposium on radio astronomy* (presented by the C.S.I.R.O.);

A. Due Rojo: *Nota sobra astronomica correteria* (presented by the author);

A. K. Lojkine: *Mount Stromlo Observatory* (presented by Mount Stromlo Observatory);

National Physical Laboratory: *MSF standard frequency transmissions* (presented by the National Physical Laboratory); and

Ministero della Pubbica Instruzione: *Osservatorio astronomico di Capodimonte a Napoli* (presented by the Observatory).

The President gave an address on the award of the Gold Medal to Professor André Danjon (see p. 401).

The President gave an address on the award of the Eddington Medal to Dr H. W. Babcock (see p. 404).

ANNUAL GENERAL MEETING OF 1958 FEBRUARY 14

Dr W. H. Steavenson, President, in the Chair

The Minutes of the preceding Annual General Meeting were read, confirmed and signed.

The Secretaries, on behalf of the Council, moved the adoption of the following resolution:—

That whenever an instrument, included in the following list and at present on loan from the Society, becomes available for loan, Council be instructed to transfer the instrument to the British Astronomical Association without further reference to a General Meeting:

No.	
153	$3\frac{1}{2}$-inch refractor with clockwork drive.
155	Two $8\frac{1}{4}$-inch $f/4$ wide-angle Xpress lenses by Ross.
156	Plane diffraction grating by Hilger.
160	$9\frac{3}{4}$-inch reflector by Slade.
161	3-inch refractor with table stand and 3 eye-pieces, 1 erecting.

Allen Instruments

18	One tripod with altazimuth mount.
19	Cooke telescope with $3\frac{1}{2}$-inch O.G. camera attachment with three double dark slides and one squared ground glass screen. One star diagonal. One Sun diagonal. Four astronomical eye-pieces. One terrestrial eye-piece. One dewcap. One sunspot projection attachment.
25 (5)	Zöllner star spectroscope.

After discussion, the resolution was adopted.

The Secretaries, on behalf of the Council, moved the adoption of the following resolution:—

That, in Bye-laws 32 and 33, the words " Geophysical Journal " be substituted for " Geophysical Supplement ".

The resolution was adopted.

The Treasurer, on behalf of the Council, moved the adoption of the following amended Bye-law 97:

" Every person who shall contribute to the property or General Funds of the Society shall be recorded as a Benefactor; and, at the discretion of Council, his name and gift shall be published in the *Monthly Notices*."

The motion was adopted.

The President having appointed the Scrutineers, the Society proceeded to the ballot for Officers and Council for the ensuing year.

The Secretary presented a summary of the Report of the Council for the year 1957.

The Treasurer gave a brief explanation of the Accounts for 1957 and a survey of the Society's financial position.

The Report of the Honorary Auditors was read (see p. 308).

A vote of thanks to the Honorary Auditors of the Treasurer's Accounts for 1957 was proposed and carried unanimously.

It was proposed and carried that the Report of the Council be received and adopted, and that it be printed and circulated in the usual manner, together with the Report of the Honorary Auditors and the President's Addresses.

The Scrutineers reported to the President the result of the ballot, and the names of the Officers and Council elected for the ensuing year were read to the meeting. (The list of names is given on p. 406.)

The thanks of the Society were given to the retiring members of Council.

The thanks of the Meeting were given to the Scrutineers of the ballot.

The Meeting then adjourned.

REPORT OF THE COUNCIL TO THE HUNDRED AND THIRTY-EIGHTH ANNUAL GENERAL MEETING OF THE SOCIETY

This report refers to the Calendar year 1957

1. *Astronomical publications.*—It will be remembered that the Council was most concerned about the delays in the publication of *Monthly Notices* and reported last year about steps taken to speed up publication. It can now be reported that these steps have had a very considerable measure of success. Our new Assistant Secretary has been working at the task of improving the speed of publication and the success of his efforts is demonstrated by the fact that during 1957 nine numbers of *Monthly Notices* were published. At the end of 1957 the average time-lag between the receipt of a paper and its publication was about six months. This contrasts with over twice that time two years ago. The Council now expects to stabilise the position, with the period between the receipt of a paper and its publication being in general not more than six months.

During the year the following were published and distributed:

Monthly Notices, Vol. **116,** Nos. 3, 4, 5, 6; Vol. **117,** Nos. 1, 2, 3, 4, 5.
Geophysical Supplement, Vol. **7,** Nos. 4, 5, 6.
Memoirs, Vol. **68,** Part I.
Occasional Notes, No. 19.

2. *Geophysical publications.*—With the success of the speeding-up programme of *Monthly Notices* in mind, the Council has turned its attention to the geophysical publication of the Society. Although the standard of the *Geophysical Supplement* has been continuously high, the delays in publication have been very great and the circulation considerably smaller than could have been hoped for. In view of these circumstances the Council referred the problem of improving our geophysical publication to the Publications Committee which held several meetings under the chairmanship of the Treasurer. The Committee were greatly influenced not only by the obvious need to accelerate production and thereby to attract more authors, but also by the fact that geophysics was a rapidly widening subject patently in need of a new journal that would appear regularly rather than at infrequent intervals like the *Geophysical Supplement*. The Council accordingly decided to wind up the *Geophysical Supplement* and to start a new journal to be called the *Geophysical Journal*. The first number of the new journal is due to appear in March 1958 and it will be published quarterly thereafter. The Council have appointed two Editors, Dr A. H. Cook and Dr T. F. Gaskell, to be responsible for the production of the new journal in collaboration with Dr R. A. Lyttleton, the Geophysical Secretary. Papers are already arriving in gratifying numbers and with the regular production promised, and the short interval expected between submission and publication, Council have little doubt that the new venture will be successful.

3. *Finance.*—During the year the Publications Committee, under the chairmanship of the Treasurer and with the advice of a Committee of the Nuffield Foundation, has made considerable efforts to improve the circulation of the Society's journals. The Society is indebted to the Foundation for a grant of £300 to enable the agreed plans for promoting the sales of the Society's publications to be carried out; and a further £200 has been promised.

The Publications Committee, as mentioned above, has attempted to give the new *Geophysical Journal* a good send-off. Leaflets advertising the *Monthly Notices* and the *Geophysical Journal* have been produced, the first issue of the latter leaflet being made in exceptionally favourable circumstances at the meeting at Toronto of the International Union of Geodesy and Geophysics. In this way the Council hopes not only to provide for an increase in the number of subscribers to the *Monthly Notices* and the *Geophysical Journal* but also to attract new Fellows.

The Publications Committee has also examined carefully the free and exchange lists of the Society with a view to effecting economies and to obtaining additional subscriptions in this manner, following the lead given by the Royal Society. The free lists have been cut down drastically and so has the free exchange list. Council fully appreciates that this must cause difficulties and even hardship to some libraries. It is a step which nevertheless cannot be avoided at the present time when Fellows must rightly expect that the Society's publications will be distributed with all possible economy. A part-exchange subscription of £3 has been introduced to meet some cases where publications are received in exchange for the publications of the Society.

The presentation of the Accounts this year has been modified so as to show separately the details of the costs of the publications and the revenue received from them; and the comparable figures for 1956 have been adjusted accordingly. In this way the net cost of the publications, the Society's main activity, will be more clearly seen. The increase in the rate of Fellows' contributions to four guineas became effective at the beginning of the year, and the prices of the publications have been increased accordingly. Unfortunately however the full effect of the increased printing costs have been felt, and other costs (including postages) have also risen. Moreover for the first year since 1945 no Grant-in-Aid for Scientific Publications has been received, consideration of the application for a grant having been deferred to July next when the full Accounts for 1957 will be available. Although therefore the Society's income has in various ways been increased by nearly £2000, the Revenue Account shows an excess of expenditure of £1338. Since, despite all care, no decrease in expenditure seems possible—in fact the increasing amount being published will add to it—further efforts to expand the sales of publications and to increase the number of Fellows will be needed.

This year's Accounts include the Quinquennial Report on the Gifts and Bequests to the Society, and there too are given the details of the Trust and Special Funds. The Archdeacon Potter Fund, the income of which was previously allocated for library purposes, has been omitted from the Special Funds as it has this year been merged with the Discarded Books Fund to form, with other monies available for library expenditures, the Library Fund. This new Fund is shown elsewhere in a separate account and in the Balance Sheet. Since the Arthur Stanley Eddington Commemoration Fund (1948) and the

Benevolent Fund (1950) are detailed in the Quinquennial Report they are being eliminated as separate items in the Balance Sheet. During the year an allocation of £255 was made from the Plummer Bequest to cover the cost of improving the ventilation in the Meeting and Council rooms (see 7, below).

4. *Membership.*—The membership of the Society during the year has substantially increased. The recent rise in the subscription is probably responsible for a somewhat increased number of resignations, but this was not as serious as was at one time feared. The membership table for 1957 is to be found on p. 307.

The Society has lost by death the following Associate:

Henry Norris Russell

and the following Fellows:

Christopher Rodney Armstrong	Earl Nelson
*Viscount Cherwell	Francis R. Openshaw
Henry Richard Didcock	*Mary Proctor
Adolph Herman Friedman	*Alexander Hamilton Rice
Edgar Odell Lovett	Henry Tompkins
Frances Lowater	Frederick Edward Townend
Sir Murdoch MacDonald	*Joseph Bernard Godsell Turner
Sydney Briton Henry Manning	*Edgar C. Willis

* Life Fellow

Obituary notices for two of these appear on pp. 311–312.

5. *Meetings.*—Eight Ordinary Meetings were held as usual in Burlington House during the year and also four Geophysical Discussions. Astronomers from overseas who attended the Society's meetings include: Dr W. Baade (Pasadena), Dr S. C. B. Gascoigne (Canberra), Dr G. E. Kron (California), Professor M. Minnaert (Utrecht), Professor A. Unsöld (Kiel) and Professor J. Witkowski (Poznan).

6. *Awards.*—The Gold Medal for 1957 was awarded to Professor Albrecht Unsöld for his work on the physics of stellar atmospheres.

The following three Associates were elected in 1957:

Dr Guillermo Haro
Dr Milton la Salle Humason
Miss Inge Lehmann

7. *Premises.*—For many years the ventilation of the Meeting Room and the Council Room has been inadequate. New fans were installed during the summer recess and have been very successful. The situation can now be regarded as satisfactory.

8. *Instruments.*—In accordance with the decision of the last Annual General Meeting, most of the Society's instruments were made over to the British Astronomical Association. Owing to legal difficulties it was not possible to make over instruments out on loan at that time, but a resolution is being submitted to

the next Annual General Meeting authorizing the transfer of instruments at present on loan upon their return to the Society.

9. *Staff.*—The Council very much regret that the protracted illness of the Librarian, Mrs M. H. Markiewicz, made it impossible for her to continue her duties. After she had been away for six months, the Council felt that permanent arrangements for the Library could no longer be deferred and it became necessary to appoint a new Librarian. The Society is very fortunate in having secured the services of Mrs J. E. Phillips who began her work as Librarian early in September 1957.

The Society is deeply indebted to Miss Wadsworth, who not only acted as Librarian during the interval, but also stayed for a further period in order to help the new Librarian to become fully familiar with the various special features of our Library. Miss Wadsworth has also very kindly consented to examine the dead correspondence of the Society stretching over many years in order to weed out irrelevant items and to rearrange those that are still of interest. It is a great help to the Society to be able to entrust this task to someone so familiar with its workings and its history.

10. *The Society's representatives.*—Representatives of the Society were appointed during the year as follows:

on the Board of Management of the Isaac Newton Observatory,
F. Hoyle, Esq., F.R.S.; and
on the Board of Visitors of the Royal Greenwich Observatory
Dr H. A. Brück.

Balance Sheet

1956 £		£	£	£
	General Fund:			
	Balance at 1957 January 1		26,096	
	Less Transfers:			
	Library Fund (Archdeacon Potter Fund)	268		
	Trust and Special Funds (Eddington Commemoration Fund: income, 1956)	12	280	
			25,816	
	Less Net loss on sale of investments	194		
26,097	Excess of Expenditure over Income for 1957	1,338	1,532	24,284
	Trust and Special Funds:			
	Capital at 1957 January 1	7,864		
	Add Arthur Stanley Eddington Commemoration Fund ..	409	8,273	
	Less Loss on sale of investments		578	
			7,695	
	Income balances at 1957 December 31		2,191	
10,347				9,886
	Library Fund, as per Account			2,532
	Repairs and Maintenance Reserve:			
	Balance at 1957 January 1		300	
	Transfer Income and Expenditure Account		150	
			450	
	Less Expenditure 1957		143	
300				307
	Sale of Discarded Books Fund:			
	Balance at 1957 January 1		2,294	
2,294	*Less* Transfer to Library Fund		2,294	
				– –
	Composition Fees Reserve Fund:			
	Balance at 1957 January 1	2,318		
	Received in 1957	153		
			2,471	
	Less 6 per cent transferred to Income and Expenditure Account		148	
2,317				2,323
	Staff Pension Fund:			
	Balance at 1957 January 1	505		
	Add Allocation from General Fund Revenue for 1957 ..	100		
			605	
	Less Pensions paid		92	
505				513
	Nuffield Foundation:			
	Grant for Advertising		300	
	Less Transfer to Publications Account		191	
				109
	Benevolent Fund: now included in Trust and Special Funds			– –
	Amounts received in advance:			
374	Contributions		208	
148	Publications, 1958		369	
				577
5,531	Sundry Creditors (including provision for printing publications for 1957, not yet completed)			3,741
£47,913				£44,272

1957 *December* 31

1956 £		£	£	£
	Investments as per Schedule:			
	General Fund, valued as at 1922 December 29 or subsequent cost		32,126	
32,429				
7,953	Trust and Special Funds, valued at cost		8,778	
				40,904
	Debtors:			
	General		1,298	
	Income Tax recoverable:			
	General Fund		384	
	Trust and Special Funds		61	
	Palomar Sky Atlas Fund		43	
	Payment under Covenant		42	
827				1,828
	Deposits at Savings Banks:			
3,700	General Fund		14	
15	Trust and Special Funds		641	
				655
	Balance on Current Account at Bank and Cash in Hand:			
1,025	General Fund		205	
1,871	Trust and Special Funds		407	
				612
	Fund Overdrawn:			
	Mr Jack Miller's Gift—Palomar Sky Atlas Fund:			
	Balance at 1957 January 1		93	
	Payments on Palomar Sky Atlas in 1957		280	
			373	
	Less Received in 1957 under Covenant	57		
	Income Tax not yet refunded	43		
			100	
93				273
£47,913				*£44,272*

Note.—Contributions unpaid at 1957 December 31, amounting to £598 1s. 0d. have not been included in these accounts.

General Fund Income and Expenditure

1956	*Expenditure*			
£		£	£	£
	To Salaries and Wages, Pension Premiums and National			
2,445	Insurance		2,675	
	„ *General Expenses :*			
	Miscellaneous Printing, including reprinting of Charter			
109	and Bye-Laws	324		
110	Postages and Packing	255		
301	Lighting and Heating	273		
215	House Expenses	214		
68	Meeting Expenses	76		
94	Insurance and Telephone	106		
111	Stationery and Office Expenses	97		
14	Travelling Expenses	57		
4	Subscriptions to National Central Library and A.S.L.I.B.	4		
63	Accountants' Fees	84		
15	Gold Medal	15		
–	Repairs to Office Furniture	4		
4	I.A.U. Telegram Service	5		
33	Sundries	65		
			1,579	
				4,254
171	„ Library Expenses (see Library Fund)			– –
132	„ Reproduction of photographic slides, prints and films ..			262
13	„ Bristol Meeting Expenses			– –
215	„ Block subscription to *The Observatory*			215
	„ *Publications Account :*			
2,072	Transfer, Excess of Expenditure over Income for 1957			3,781
	„ *Transfers :*			
	Staff Pension Fund		100	
	Library Fund		100	
	Repairs and Maintenance Reserve		150	
363				350
	„ Excess of Income over Expenditure for 1956,			
83	transferred to General Fund			– –
£6,635				£8,862

To the Fellows of THE ROYAL ASTRONOMICAL SOCIETY

We have examined the above Balance Sheet and Accounts with the books and vouchers information and explanations given to us. We have verified the Investments, and Balances at which have been inspected by the Society's Honorary Auditors.

FINSBURY CIRCUS HOUSE,
BLOMFIELD STREET, LONDON, E.C.2.
1958 *January* 22.

Account for the year ended 1957 *December* 31

1956 £		*Income*	£	£	£
	By	*Amounts received from Fellows :*			
		Admission Fees :			
		Current year	111		
		Arrears	19		
		Annual contributions :			
		Current year	3,739		
		Arrears	110		
3,077				3,979	
	,,	*Composition Fees :*			
148		Transfer from Reserve Account		148	
250	,,	Special donations from Compounders		50	
100	,,	Mr Jack Miller's Benefaction		100	
					4,277
1,241	,,	Interest and Dividends (less foreign taxation)		1,449	
121	,,	Interest on Bank Deposit Accounts		18	
					1,467
	,,	*Miscellaneous Receipts :*			
		Sale of Palomar Slides and Prints		255	
		Sale of R.A.S. Slides and Prints		62	
		Loan of Films		36	
		British Astronomical Association		168	
		London Mathematical Society		40	
		Sundries		19	
498					580
	,,	*Editorial Services :*			
1,200		Charged to Publications Account			1,200
	,,	Excess of Expenditure over Income for 1957, transferred			
– –		to General Fund			1,338
£6,635					£8,862

relating thereto, and certify them to be correctly drawn up therefrom, and in accordance with the Banks. We have not examined the records relating to contributions and admission fees of Fellows,

W. B. KEEN & CO.,
Chartered Accountants.

General Fund Income and Expenditure

Publications

1956 £		*Expenditure*	£	£	£
		To Printing, etc.			
		Monthly Notices :			
		Vol. 117, Nos. 1–5	2,896		
		„ No. 6 (estimated)	650		
		Vol. 116 (balance of cost not provided in 1956)	266		
		Vols. 115 and 116 (binding)	38		
				3,850	
		Geophysical Supplement :			
		Vol. 7, No. 6	437		
		„ Nos. 4 and 5 (balance of cost not provided in 1956)	192		
				629	
		Occasional Notes, Vol. 3, No. 19		56	
		Memoirs, Vol. 68, No. 1		213	
		Reprints		1,061	
		„ Paper Supply		932	
		„ Postages and Packing		642	
	5,730				7,383
	1,850	*Less* Parliamentary Grant-in-Aid for Scientific Publications through the Royal Society			– –
3,880					
–		„ Advertising leaflets (see contra)			191
1,200		„ Transfer, General Fund Income and Expenditure Account, for editorial sevices			1,200
£5,080					£8,774

Library

1957			£	£
Dec. 31	To *Costs :*			
		Purchases of Books and Periodicals	163	
		Binding of Books and Periodicals	123	
	„	General Expenses	32	
				318
„	„	Balance carried to Balance Sheet		2,532
				£2,850

Account for the year ending 1957 *December* 31

Account

1956 £	*Income*	£	£
	By Sales :		
	Monthly Notices, Vol. 117	1,934	
	„ „ Vol. 116	31	
	„ „ Vol. 115 and earlier	129	
	Geophysical Supplements	644	
	Memoirs, *Occasional Notes* and miscellaneous sales	490	
	Reprints	1,283	
	Part-Exchange subscriptions	291	
3,008			4,802
	„ Nuffield Foundation Grant :		
	Allocated for advertising		191
	„ Transfer, General Fund Income and Expenditure Account, being		
2,072	excess of Expenditure over Income for the year		3,781
£5,080			£8,774

Fund

1957		£	£
Jan. 1	By *Balances transferred :*		
	Sale of Discarded Books Fund		2,294
	General Fund (Potter Fund)		268
Dec 31	„ *Trust income transferred :*		
	Turnor and Horrocks Fund	35	
	Harry Watson Fund	153	
			188
„	„ *General Fund :*		
	Allocation from income for 1957		100
			£2,850

Nominal				*Book Value*					
			Fixed Interest Stocks	£	*s.*	*d.*	£	*s.*	*d.*
£1000	0	0	Bowater Paper Corporation Ltd. 5¾ per cent Conv. Unsec. Loan Stock 1978/82	1,021	18	0			
£3100	0	0	British Electricity 4¼ per cent Guaranteed Stock, Stock 1974/79	3,264	7	3			
£800	0	0	Conversion 4¼ per cent Stock 1962	775	2	5			
£1000	0	0	Imperial Chemical Industries Ltd. 5½ per cent Conv. Unsec. Loan Stock 1977/79	1,135	13	7			
£5548	13	7	Treasury 3 per cent Stock 1966 or after	4,126	19	7			
			(Market Value £8,288)				10,324	0	10
			Sterling Industrial Equities						
600			Apex (Trinidad) Oilfields Ltd. Ord. 5*s.* Stock Units	1,216	18	6			
£300			Associated Electrical Industries Ltd. Ord. Stock	754	1	6			
1,800			British Motor Corpn. 5*s.* Ord. Shares	888	6	6			
500			British Tabulating Machine Co. Ltd. £1 Ord. Shares	1,131	7	0			
£500			Courtaulds, Ltd. Ord. Stock	924	11	6			
700			Dunlop Rubber Co. Ltd. 10*s.* Ord. Stock Units ..	993	15	3			
£300			English Electric Co. Ltd. Ord. Stock	886	1	6			
40			Hudson's Bay Co. £1 Ord. Shares	394	4	6			
500			London & Thames Haven Oil Wharves Ltd. 4*s.* Ord. Shares	353	6	5			
£600			P. & O. Steam Navigation Co. Deferred Stock ..	971	9	0			
£600			Porrits & Spencer Ltd. Ord. Stock	1,010	4	0			
800			Richardsons, Westgarth & Co. Ltd. 5*s.* Stock Units	834	16	6			
£150			Shell Transport & Trading Co. Ltd. Ord. Stock	1,320	6	0			
600			South African Distilleries & Wines Ltd. £1 Ord. Stock Units	914	0	3			
750			United Molasses Co. Ltd. 10*s.* Stock Units ..	1,342	16	0			
			(Market Value £11,584)				13,936	4	5
			Canadian Industrial Equities						
60			Canadian Bank of Commerce Capital Stock $10 P.V. Shares	1,190	14	11			
60			Dominion Stores Ltd. N.P.V. Shares	1,017	6	0			
50			Imperial Oil Ltd. N.P.V. Shares	1,080	6	6			
20			Power Corporation of Canada Ltd. N.P.V. Shares	477	4	6			
			(Market Value £3,391)				3,765	11	11
			U.S.A. Industrial Equities						
100			International Utilities Corpn. Common $5 P.V. Shares	1,044	3	5			
40			Texas Co. Common $25 P.V. Shares	1,016	18	0			
80			Tri-Continental Corpn. Common $1 Shares ..	989	4	0			
45			U.S. Steel Corpn. Common $16⅔ P.V. Shares ..	1,050	5	11			
			(Market Value £3,514)				4,100	11	4
			(Total Market Value £26,777)				£32,126	8	6

Trust and Special Funds Investments on 1957 December 31

Nominal				*Cost*		
£	*s.*	*d.*		£	*s.*	*d.*
457	4	5	British Electricity 4¼ per cent Guaranteed Stock 1974/79 ..	404	12	10
1,000	0	0	Conversion 4¼ per cent Stock 1962	994	5	3
100	0	0	4 per cent Defence Bonds	100	0	0
375	0	0	Savings 3 per cent Bonds 1955/65	376	4	5
1,765	17	8	„ „ „ 1960/70	1,765	17	8
5,247	6	5	Treasury 3 per cent Stock 1966 or after	3,303	17	3
1,902	6	3	3½ per cent War Stock	1,833	0	1
			(Market Value £7,176)	£8,777	17	6

Quinquennial Report

Gifts to the General Funds and Property of the Society

The John Lee Gift (1836 and 1844): In 1836 John Lee, Esq., LL.D., gave the Advowson of the living of Hartwell; in 1844 he gave the Advowson of the living of Stone, Bucks. In 1879 these Advowsons were purchased by his heir, Edward Lee, Esq., for £700.

The Lawson Bequest (1856): Henry Lawson, Esq., bequeathed to the Society the sum of £200, free of legacy duty.

The Carrington Bequest (1876): R. C. Carrington, Esq., F.R.S., bequeathed to the Society £2000 Consols.

The Lambert Bequest (1877): C. J. Lambert, Esq., presented to the Society the sum of £500 free of legacy duty, being part of a sum of money bequeathed by his father, Charles Lambert, Esq., for scientific purposes.

The McClean Bequest (1905): Frank McClean, Esq., LL.D., F.R.S., bequeathed to the Society the sum of £2000, free of legacy duty.

The Farrar Bequest (1906): The Rev. A. S. Farrar, D.D., bequeathed to the Society the sum of £100, free of legacy duty.

The Parsons Gift (1922): The Hon. Sir Charles Parsons, K.C.B., F.R.S., gave to the Society £2500 War Stock 1929–47, in memory of his father, the 3rd Earl of Rosse, who made the 6-foot reflector, and who died 1876 October 31.

The Grove-Hills Bequest (1922): Colonel E. H. Grove-Hills, C.M.G., F.R.S., bequeathed to the Society, free of legacy duty, his collection of early astronomical and mathematical books up to the year 1700, together with a sum of £250 to cover the expenses incurred by the Society in connection with the books.

The Grove-Hills Fund (1922): In 1922 the Treasurer, Colonel Grove-Hills, collected by his private efforts, with the approval of the Council, a Special Fund to meet the immediate financial difficulties of the Society. The total amount received from all sources (including dividends on the investments representing the fund) was £1913 1*s.* 11*d.*

The Lindemann Bequest (1931): A. F. Lindemann, Esq., bequeathed to the Society the sum of £1000, free of legacy duty.

The Archdeacon Potter Bequest (1933): Archdeacon Beresford Potter, who died 1931 May 10, bequeathed to the Society 3/88th share of residuary estate. The Council allocated the income of the fund for the purposes of the library, and in 1957 transferred the whole fund, then amounting to £268 2*s.* 6*d.*, to the newly-formed Library Fund (*see Balance Sheet*).

The Goodridge Bequest (1936): Captain J. J. L. Goodridge, who died 1936 March 13, bequeathed to the Society the sum of £50, free of legacy duty.

The Herbert Spencer Bequest (1936): Herbert Spencer, Esq., who died in 1903, nominated the Royal Astronomical Society as one of twelve Learned Societies to be eventual beneficiaries of his residuary estate. His estate was wound up in 1936, and the Society's share of the residue amounted to £1241. The conditions of acceptance of the legacy were that the sum received should be spent in certain specified ways by the Governing Body within five years of the date of payment, and might not be used in any way for purposes of endowment. The bequest was finally expended during 1941.

The Lindley Bequest (1937): Miss Julia Lindley bequeathed to the Society the sum of £1000, free of legacy duty.

The Stanley Williams Bequest (1939): A. Stanley Williams, Esq., who died 1938 November 21, bequeathed to the Society all his astronomical instruments, books, maps, photographs, manuscripts, etc., together with the sum of £200, free of legacy duty, for the reduction or publication of his observations of variable stars; and also a further sum of £100, free of legacy duty, for the furtherance of astronomy in general or of the Society in particular, in such manner as the Council of the Society may think fit.

The E. W. Brown Trust (1939) (*see below*).

The Plummer Bequest (1946) (*see below*).

The Carder-Davies Bequest (1948): D. Carder-Davies, Esq., bequeathed to the Society the sum of £3000, free of duty and without any condition, other than the expression of a wish that no part be spent on any purpose controlled or suggested by Government.

The M. A. Nadarov Bequest (1950) (*see below*).

The Stephan Kuffner Gift (1950): The valuable library of the von Kuffner Sternwarte, a private observatory in Vienna, was given jointly to the Society and to the Royal Greenwich Observatory by the son of the late owner. Sales of the books not required by the libraries of the Society or the Observatory, mostly duplicates, have realised about £1800. This sum has been included in the Library Fund (*see Balance Sheet*).

The W. H. Owston Bequest (1951): William Henry Owston, Esq., who died 1950 December 15, after making some personal bequests left the residue of his estate to the Society. The investment and cash received totalled in value £3951 15*s.* 5*d.*

The Harold Pain Bequest (1953): Rev. Harold Pain bequeathed to the Society the sum of £250 for solar research.

The Wilfred Hall Bequest (1953): Under the terms of the will of Wilfred Hall Esq., D.Sc., the Society was offered his twin 15-inch Grubb equatorial telescope and accessories, with £500 towards the cost of removal and re-erection. The offer was accepted and the instrument was loaned to the municipality of Preston for the Jeremiah Horrocks Observatory. It was installed in a new observatory, the Wilfred Hall Observatory, at Alston, which was opened on 1957 November 6.

The Jack Miller Gift (1954): Under a seven-year covenant to pay £100 gross annually Mr Jack Miller made provision for the purchase by the Society of the National Geographic Society–Palomar Observatory Sky Atlas, estimated to cost $2000, and a cabinet to accommodate it.*

The Luck Bequest (1955): S. I. Luck, Esq., O.B.E., bequeathed to the Society the sum of £200.

Special Funds

The Victor Nadarov Fund (1950): Mrs M. A. Nadarov bequeathed to the Society one-half of her residuary estate. The estate was wound up in 1950, and the Society's share amounted to £725. Under the terms of the legacy the Fund is to be devoted to the encouragement and promotion of the study of sunspots and is to be known as the Victor Nadarov Fund: subject to this condition, the Fund can be used, both as to principal and accumulated interest, in whatever way the Council considers most suitable.

The investments of the Fund are:

£100 Defence 4 per cent Bonds
£375 Savings 3 per cent Bonds 1955/65
£100 Savings 3 per cent Bonds 1960/70
£250 War 3½ per cent Stock

The Defence Bonds include £88 12*s.* 0*d.* income balance invested in 1951 February.

	£	*s.*	*d.*		£	*s.*	*d.*
1953 Jan. 1. Balance of Fund...	175	0	5	1957 Dec. 31. Balance of Fund	314	7	10
1953–57. Five years' income from investments and Bank Deposits	139	7	5				
	£314	7	10		£314	7	10

The Arthur Stanley Eddington Commemoration Fund (1948): The Council of the Society decided to commemorate the services to astronomy and to the Society of Sir Arthur Stanley Eddington, O.M., F.R.S., by instituting a gold medal to be known as the Eddington Medal. As the result of an appeal to all Fellows of the Society, a total sum of £534 2*s.* 6*d.* was raised.

The investment representing the Fund is:

£662 11*s.* 0*d.* Treasury 3 per cent Stock

* Up to the time of Mr Miller's death in 1958, £500 had been received under this covenant.

	£	s.	d.		£	s.	d.
1953 Jan. 1. Balance of Fund...	45	17	9	1953–57. Cost of medals ...	34	7	0
1953–57. Five years' income from investments and Bank Deposits	80	2	5	1957 Dec. 31. Balance of Fund	91	13	2
	£126	0	2		£126	0	2

The Benevolent Fund (1950): The family of the late Sir Frank Dyson, K.B.E., F.R.S., have assigned to the Society their share of the royalties received from the publishers of *Eclipses of the Sun and Moon* by Sir Frank Dyson and R. v. d. R. Woolley, to form the nucleus of a Benevolent Fund, to be used at the discretion of the Council.

	£	s.	d.		£	s.	d.
1953 Jan. 1. Balance of Fund...	6	15	2	1953–57. Grants made ...	3	3	0
1953–57. Donations and royalties received...	21	19	2	1957 Dec. 31. Balance of Fund	25	11	4
	£28	14	4		£28	14	4

Trust Funds

The Lee and Janson Fund (1834 and 1879): In 1834 John Lee, Esq., LL.D., gave £100, and in 1879 T. C. Janson, Esq. bequeathed £200, the interest to be given to the widow or orphan of a deceased Fellow.

The investment representing the Fund is:

£309 16*s.* 0*d.* Savings 3 per cent Bonds 1960/70

	£	s.	d.		£	s.	d.
1953 Jan. 1. Balance of Fund...	96	9	8	1955 Grants made	50	0	0
1953–57. Five years' income from investment and Bank Deposits	52	19	0	1957 Dec. 31. Balance of Fund	99	8	8
	£149	8	8		£149	8	8

The Turnor Fund and the Horrocks Memorial Fund (1853 and 1876): In 1853 the Rev. Charles Turnor, M.A., bequeathed a sum of £500; and in 1876 the Society received a sum of £38 15*s.*, the unexpended balance of a fund collected for the purpose of erecting a memorial in Westminster Abbey to Jeremiah Horrocks, to which the Society added the sum of £55 15*s.* The income from the Fund so formed is to be used in the purchase of books for the Library.

The investment representing the Fund is:

£526 3*s.* 6*d.* Savings 3 per cent Bonds 1960/70

	£	s.	d.		£	s.	d.
1953 Jan. 1. Balance of Fund...	1	4	6	1953–57. Purchases of books ...	45	13	10
1953–57. Five years' income from investment and Bank Deposits	78	18	10	1957 Dec. 31. To Library Fund	34	9	6
	£80	3	4		£80	3	4

The Hannah Jackson (née Gwilt) Fund (1861): In 1861 Mrs Hannah Jackson (*née* Gwilt) gave £300 Consols. The interest of the Fund is to be given in medals or other awards in accordance with the terms of the Trust.

The investment representing the Fund is:

£287 Savings 3 per cent Bonds 1960/70

	£	s.	d.		£	s.	d.
1953 Jan. 1. Balance of Fund...	39	16	3	1953–57. Awards and medals given...	50	10	6
1953–57. Five years' income from investments and Bank Deposits	44	17	4	1957 Dec. 31. Balance of Fund	34	3	1
	£84	13	7		£84	13	7

The Harry Watson Memorial Fund (1923): In 1920 Mrs Watson presented to the Society the sum of £300 as a memorial to her late husband, Lieut.-Col. Harry James Watson, F.R.A.S., the interest on this sum to be used for the purchase of books for the library, such books to be indicated by a special book-plate. In 1923 Mrs Watson bequeathed a further sum of £958 17*s.* to the Society. The Council resolved that these two sums should together constitute a Trust Fund, the income from which is to be used for the purchase and binding of books.

The investments of the Fund are:

£542 18*s.* 2*d.* Savings 3 per cent Bonds 1960/70

£1253 18*s.* 6*d.* Treasury 3 per cent Stock

	£	s.	d.		£	s.	d.
1953 Jan. 1. Balance of Fund...	282	5	4	1953–57. Purchases of books ...	467	3	10
1953–57. Five years' income from investments and Bank Deposits	337	12	9	1957 Dec. 31. To Library Fund	152	14	3
	£619	18	1		£619	18	1

The George Darwin Lectureship Fund (1926): In 1926 Sir James Jeans presented to the Society the sum of £1000 for the endowment of an annual lectureship, to be called *The George Darwin Lectureship*, the lecture to be on some subject of interest to astronomers, preference being given, in electing a lecturer, to one normally resident outside the British Isles.

The investment representing the Fund is:

£1261 17*s.* 6*d.* Treasury 3 per cent Stock

	£	s.	d.		£	s.	d.
1953 Jan. 1. Balance of Fund...	156	11	6	1953–55. Lectureship fees paid	150	0	0
1953–57. Five years' income from investments and Bank Deposits	218	6	1	1957 Dec. 31. Lectureship fees due (reserve)	100	0	0
				1957 Dec. 31. Balance of Fund	124	17	7
	£374	17	7		£374	17	7

The A. G. Stillhamer Trust (1937): A. G. Stillhamer, Esq., of Bloomington, Illinois, left all his property outright to Miss Maude S. Capps, of Bloomington; but, on account of certain personal memoranda and conversation between Mr Stillhamer and Miss Capps, the latter resolved to carry out what she believed to have been Mr Stillhamer's wishes by the payment to the Royal Astronomical

Society of the sum of 2500 dollars in cash, the conditions of acceptance being that the principal is to remain intact in the endowment fund of the Society. The income is to be used (not necessarily annually) to pay expenses of scientific research or to purchase definite scientific instruments for use in scientific instruction or research.

The investment representing the Fund is :

£491 10*s.* 0*d.* War 3½ per cent Stock

	£	*s.*	*d.*		£	*s.*	*d.*
1953 Jan. 1. Balance of Fund...	283	15	4	1957 Dec. 31. Balance of Fund	390	13	1
1953–57. Five years' income from investments and Bank Deposits	106	17	9				
	£390	13	1		£390	13	1

The E. W. Brown Trust (1939) : E. W. Brown, Esq., M.A., Sc.D., F.R.S., who died in 1938, bequeathed to the Society the sum of five thousand dollars, and desired that the income from the bequest should be used for assistance in the calculation of accurate orbits of the bodies of the solar system, such income as should not be used for this purpose being used for the general purposes of the Society.

The investment representing the Fund is :

£1160 16*s.* 3*d.* War 3½ per cent Stock

	£	*s.*	*d.*		£	*s.*	*d.*
1953 Jan. 1. Balance of Fund ...	344	1	3	1957 Dec. 31. Balance of Fund	580	10	6
1953–57. Five years' income from investments and Bank Deposits	236	9	3				
	£580	10	6		£580	10	6

The Plummer Bequest (1946) : H. C. Plummer, Esq., M.A., F.R.S., bequeathed to the Society the sum of £1000, to be invested and treated as a Trust Fund, the income to be at the disposal of the Council for all purposes, with a recommendation that it should consider the possibility from time to time of helping the Norman Lockyer Observatory. The Society was also named as one of the residuary legatees. In 1947 the Society received £1500 from the estate and in 1956 a further £404 12*s.* 10*d.*

The investments of the Fund are :

£457 4*s.* 5*d.* British Electricity 4¼ per cent Stock 1974/79

£2068 19*s.* 5*d.* Treasury 3 per cent Stock

	£	*s.*	*d.*		£	*s.*	*d.*
1953 Jan. 1. Balance of Fund ...	220	13	4	1957. Allocations :			
1953–57. Five years' income from investments and Bank Deposits	265	9	9	Norman Lockyer Observatory	30	0	0
				Part cost of ventilation improvements	26	5	0
				Balance for ventilation improvements (reserve)	229	0	0
				1957 Dec. 31. Balance of Fund	200	18	1
	£486	3	1		£486	3	1

Income Balances of Funds

The accumulated income balances of the Trust and Special Funds are held at the Bank, in Savings Banks, and invested in Trustee Stock.

On 1957 December 31 the holdings were :

	£	s.	d.
£1000 Conversion 4½ per cent Loan, 1962 (at cost) ...	994	5	3
£88 12*s.* 0*d.* Defence 4 per cent Bonds (at cost) ...	88	12	0
London Trustee Savings Bank Deposit	640	17	7
On Current Account at Bank	406	16	9
	£2130	11	7
Income Tax recoverable	60	11	9
Total accumulated income (*see Balance Sheet*) ...	£2191	3	4

PROGRESS AND PRESENT STATE OF THE SOCIETY

	Patron	Institutional Members	Fellows: Compounded	Fellows: Annual Contributors	Junior Members	Associates	Total
1957 January 1	1	6	189	926	36	51	1209
Since elected	...	1	...	110	12	3	126
Junior Members elected to Fellowship ..	...	...	...	5	− 5	...	0
Deceased 1957	...	...	− 6	−10	...	− 1	−17
Deceased before 1957, notified 1957 ..	...	...	...	− 1	...	...	− 1
Since compounded	...	...	2	− 2	...	...	0
Resigned 1957	...	...	...	−16	− 2	...	−18
Removed	...	...	...	− 9	− 6	...	−15
1958 January 1	1	7	185	1003	35	53	1284

(N.B.—Fourteen Associates are also Fellows, and are therefore counted twice in the above table.)

REPORT OF THE HONORARY AUDITORS FOR THE YEAR 1957

We have examined the professionally audited accounts of the Society and have checked the official list of Fellows against the subscriptions received. The year 1957 saw a substantial increase of membership. We note with regret that a number of Fellows have failed to take notice of the increase in subscription despite several reminders.

We have examined the premises of the Society and note with satisfaction:

(1) The well-maintained cleanliness and orderliness throughout the building.

(2) The greatly improved condition of the Caretaker's Bedroom and Kitchen.

(3) The much-improved lighting arrangements in the Secretarial Offices through a simple and economic alteration of lamps and globes.

(4) The newly-installed ventilating system in the Meeting and Council Rooms.

With less satisfaction we note the following:

(5) The bad illumination of the reading table in the Upper Library.

(6) The poor decorative order of the Caretaker's Spare Bedroom.

(7) The still disorderly state of the chart case in the Main Library.

(8) The beginning of the flaking-off of the paint work on the walls and ceiling of the staircase and the poor condition of the window frames of the upper staircase.

We understand that arrangements are now in hand for clearing up the chart case. We strongly recommend that steps be taken to improve the illumination of the reading table in the Upper Library and we think that a table-lamp and a better table covering than the existing one will help towards this end. We recommend that the Caretaker's Spare Bedroom be redecorated.

In view of the fact that a number of foreign Fellows have failed to pay their subscriptions, and that cases are known to us where Fellows living abroad find it difficult to obtain the necessary sterling exchange for the want of an official invoice, we suggest that the Council considers the desirability of sending invoices in such cases sufficiently in advance of the renewal date.

Finally, we wish to acknowledge the ready assistance given to us by the Assistant Secretary throughout the audit.

T. KIANG.
B. P. DASH.

LIST OF PUBLIC INSTITUTIONS AND OF PERSONS WHO HAVE PRESENTED GIFTS (OTHER THAN BY EXCHANGE) TO THE LIBRARY DURING THE YEAR 1957

Académie Serbe des Sciences
Academy of Sciences, U.S.S.R.
Ankara University
Astronomical Society of South Africa
Astronomical Society of Tasmania
Astronomische Gesellschaft
British Astronomical Association, N.S.W. Branch
Cambridge University Press
Cartuja Observatory
Centre National de la Recherche Scientifique
Chapman and Hall
Defence Research Board, Canada
The Editors of *Discovery*
The Free Press
Geophysical Institute of the Faculty of Science, University of Zagreb
Geophysical Society of Finland
Griffith Observatory
H.M. Nautical Almanac Office
Harvard College Observatory
Harvard University Press
High Altitude Observatory, Boulder, Colorado
Hutchinson and Co.
Imperial Chemical Industries
Institut d'Astrophysique de l'Université de Liège
International Astronomical Union
International Council of Scientific Unions
International Scientific Radio Union
The Editors of *La Nature*
Frederick Muller, Ltd.
National Research Council of Canada
Norman Lockyer Observatory
Observatoire du Houga
Oporto, Faculdade de Sciências
Oxford University Press
Perkin-Elmer Corporation
Phoenix House, Ltd.
Sir Isaac Pitman and Co. Ltd.
The Editors of *Research*
The Editors of *Rise Hvezd*
Royal Alfred Observatory, Mauritius
Royal Meteorological Society
Science Council of Japan
The Editors of *Scientific American*
Sky Publishing Corporation
Sociedad Astronómica de Mexico
Societas Scientiarum Fennica

Specola Astronomica Vaticana
The Editors of *Urania*
The Editors of *Vega*
Victoria and Albert Museum
Yale-Columbia Southern Station
Carl Zeiss Verlag

Mr M. Allé
Dr A. Armitage
Dr R. Hanbury Brown
Professor T. G. Cowling
Dr M. G. De Vaucouleurs
Mr A. Galle
Mr A. Gautier
Professor H. Hagihara
Professor O. Heckmann
Sir Harold Jeffreys
Professor M. Kamienski
Mr F. Kępiński
Capt R. Lloyd-James
Professor A. C. B. Lovell
Mr W. J. Luyten
Professor G. C. McVittie
Mr B. Y. Mills
Professor V. Narlikar
Mrs M. S. Sargent
Professor F. J. M. Stratton
Mr L. Thorndike
Professor S. K. Vsessvyatski
Mr N. E. Wagman
Professor M. Waldmeier
Mr L. Weineck
Flt-Lt F. Whalley

OBITUARY NOTICES

HENRY NORRIS RUSSELL was born on 1877 October 25. His many publications are so well treated by F. J. M. Stratton in *Biographical Memoirs of Fellows of The Royal Society* (Vol. 3, November 1957) that little remains to be added in that respect. It does seem worthwhile to mention his early theoretical study of the absolute magnitude of a star which radiates as a black body. Perhaps, because he had insufficient confidence in the physical postulates involved, his brilliant equations were not published for years and then they appeared, buried alive as it were, in a textbook (*Astronomy*, Chapter XXI). Included also was a final table of stellar temperatures which became at once, to his amusement, standard, although compiled only for instructional purposes.

Preparation for this textbook, strangely enough, launched him about 1912 upon the first really productive period of his career in research, as his old friend, the late Professor Frank Schlesinger, once remarked. Russell's dissatisfaction with available data in several branches of astronomy led him to make side excursions into research investigations designed to remedy these deficiencies; and little progress was made with the book itself. After about twelve years of such progress the publishers justifiably became impatient; he called two colleagues to his rescue and the text was at last finished in 1926.

By a second odd chance, a small undergraduate course in practical astronomy, which he offered during a term in the early 1920's, resulted in calling his attention to the rapid developments physicists were making then in the understanding of atomic spectra. Soon he had made important contributions to that field of physics, where only his rigid, ingrained and surprising conservatism prevented his scaling the heights to a Nobel prize. The Bohr atom satisfied him too much too soon.

This conservatism showed most strongly in his acceptance of the Laplacian idea of the full mechanistic determination of all things, as expressed by Russell during many years of informal and formal talks about "fate and freedom". His Presbyterian theology was for him satisfied by the point that, although everything we do is fore-ordained in minute detail, the mathematical equations which govern all contain so many variables that their solution is humanly impossible. Consequently, we must conduct ourselves as though we really possessed free will. An irreverent, but nonetheless admiring, graduate student, nicknamed these talks "chemical Christianity". Later, of course, Heisenberg knocked out Laplace's base in physics, while leaving theology untouched.

Russell's mental equipment was superb—enough to have powered several geniuses—and until late in life his physical stamina and his industry matched it. He was fortunate in possessing a good training in physics at a time when few other astronomers had any to speak of. His skill in mental arithmetic helped too. He retained throughout his life a high regard for his predecessor and teacher at Princeton, Charles A. Young. He was widely read, familiar with the humanities, and had an unusual memory. But for all his liberal classical education and his acquaintance with many diverse subjects, his heart was wholly with physical science.

His greatest strength lay in his ability quickly to apply standard theory for displaying the essential consequences of whatever observational data in astro-

nomy or physics he chose to attack—aided by his never-absent slide rule, and unimpeded by any excess of mathematical-statistical methodology. He was very much an " old Princetonian " in his own unique way, a product of a place and a period that in less crowded days than ours would be living still in legend.

Russell was elected a Fellow of the Society in 1903 and an Associate in 1916. He died on 1957 February 18.

JOHN Q. STEWART.

JOSEPH BERNARD GODSELL TURNER was born in South Africa on 1907 April 15 and joined the staff of the Cape Observatory in 1925, rising to the rank of the Higher Observatory Officer there.

His work in the Cape Observatory from 1926 till his death on 1957 May 22 concerned stellar parallax, first under the direction of Mr J. W. Jackson and then under the immediate direction of H.M. Astronomer. During this time 1800 parallax determinations were made and he was the only member of the staff who worked on the programme throughout.

He assisted in the Cashier's Department of Simonstown Dockyard for most of the war and in spite of indifferent health worked long hours, bearing a heavy share of the tremendous amount of work that fell to that department.

He was of a shy and retiring nature but endeared himself to his fellow-workers. He took an active part in the affairs of the Astronomical Society of South Africa, being for some time its Treasurer. He was elected a Fellow of our Society on 1938 January 14.

J. JACKSON.

PROCEEDINGS OF OBSERVATORIES

Royal Greenwich Observatory

(*Director, Dr R. v. d. R. Woolley, O.B.E., F.R.S., Astronomer Royal*)

Considerable progress has been made with the erection of the equatorial telescopes, and in the year 1957 the installation of the 30-inch reflector, the 20-inch reflector (Isaac Roberts telescope), and the 28-inch refractor was completed, and fair progress made with the astrographic and 26-inch refractors. The domes have not yet been handed over finally to the Astronomer Royal by the Admiralty Engineers, and some interruptions to observations occur while attention is given to these domes. Some photoelectric observations have, however, been secured with the 30-inch and 20-inch reflectors, and a few observations of double stars secured with the 28-inch refractor, with both the filar micrometer and the comparison image micrometer.

The West Block of administrative offices and workshops is now nearly complete, and the Nautical Almanac Office and the Departments of Time, Astrometry, and Astrophysics are working in their new offices. Demolition of the temporary buildings south of the Castle has commenced.

Meridian department

Cooke Transit Circle.—The training of a new team of observers for the T.C. is complete and the full-time operation of this instrument on the international programme of observation of the AGK3 Reference Stars was commenced on October 22.

Before that date 4700 transits were observed. From October 22 to the end of the year observations of Sun, planets and stars total 2600.

The prototype electronic apparatus, designed to eliminate the use of pen chronographs by the automatic recording of transit times directly on to Hollerith cards, was operated for some weeks, but proved unreliable through the use of unsuitable components. The construction of a more reliable model is nearly completed.

The machine used to measure the circle-reading camera films was fitted with a commercially-supplied digitiser, designed to punch the circle readings on cards directly, but this is also giving trouble and has been returned to the makers.

Photographic Zenith Tube.—During the year, 2463 stars were observed on 271 plates. The reductions of plate measures and the calculations of apparent places of stars have been carried out on the punched-card machines of H.M. Nautical Almanac Office. The strobotron timing-gear has been superseded by a set of contacts directly operated by the moving carriage; this greatly reduces the measuring load, and will reduce it still further when the times are directly punched on cards, as it is planned to do when possible. The contacts were specially made by Messrs Grubb, Parsons, and tests show that the net effect of any mechanical backlash is less than a millisecond.

Observations made during the first half of the year have been combined with the observations made during 1955–56, for determining corrections to the

provisionally adopted star places. These corrections have been applied retrospectively and the finally adopted latitudes and clock errors for the whole period up to the end of 1957 have been collected and published in a circular.

From internal evidence on a single plate it has been found that the p.e. of the observation of a single star whose zenith distance is zero is $\pm 0''\cdot07$ in each co-ordinate. This figure is confirmed by the comparison of the corrections deduced to individual star places within their groups. Using nights on which six or more plates were obtained, the external probable error of a plate of weight 10, judged by the plate-residual from the mean for the night, is $\pm 0''\cdot04$ in each co-ordinate.

Time service.—Astronomical observations for the determination of time with small transit C in the Courtyard Dome at Greenwich ceased following an observation on April 23 at $03^h\cdot9$. The instrument was transferred to the new transit pavilion at Herstmonceux, and the first observation obtained on April 23 at $20^h\cdot0$. After a period of further overlap with the Photographic Zenith Tube observations, transit C was withdrawn from service on October 16, having been used for 49 observations at Greenwich (since the P.Z.T. became usable for time) and 91 at Herstmonceux. From October 16 the P.Z.T. observations were used exclusively in current work, and from July for the establishment of the time system of the Time Service Bulletin. Throughout the year corrections computed by the Bureau International de l'Heure have been applied for the effects of annual fluctuation and polar variation.

The time signal work at Greenwich was closed on April 23. Daily reception of GBZ commenced at Herstmonceux on May 28, and its effective use for the Bulletin started on July 21. British and foreign short-wave receptions were effectively transferred as from August 1 and August 15 respectively. From July 1 the 1000 GBZ signals were transmitted from Herstmonceux, but the associated short-wave transmissions at 1000 (GKU5 and GIC37), and all the 1800 signals, were controlled from Abinger until July 22, when all signals were emitted from Herstmonceux. Receptions continued at Abinger until August 14, as a standby; from August 15 all operation work of the Time Service was carried out at Herstmonceux.

Signals are received by land-line at Herstmonceux from the clocks EB at the Post Office Radio Branch Laboratories and Q26 at the National Physical Laboratory. The signals consist of an alternating current at a frequency of 1 kc/s derived from EB and $2\frac{1}{2}$ kc/s derived from Q26: at Herstmonceux the two frequencies are separated and multiplied up to 100 kc/s. In this way continuous intercomparisons are shown by the rotary beat-counters between the Herstmonceux clocks and EB (since July 4) and Q26 (since July 23). The availability of these two clocks has been of great value during the period of transfer of the Observatory clocks from Abinger to Herstmonceux, and the Astronomer Royal is indebted to the Engineer-in-Chief, Post Office, and the Director, National Physical Laboratory, for this continued co-operation.

The programme of reception of foreign radio time signals and of British short-wave signals has been on a somewhat reduced scale since the transfer to Herstmonceux, largely owing to the delay in the completion of the aerials. Additional equipment for time distribution within the Observatory and for time and frequency comparisons is planned. Two of the best ring crystals, which were left running as long as possible at Abinger in order to serve as standards during

the transfer period, remain to be installed at Herstmonceux, but six are installed and working.

For the measurement of radio time signals under indifferent reception conditions, a prototype visual display unit has been installed; this has proved very useful and has offset, to some extent, the lack of good aerial facilities.

Information relating to the caesium resonator at the National Physical Laboratory has been communicated regularly and has been of value in the assessment of clock performance. The results are not at present being used, even indirectly, in the establishment of UT2 at the Royal Observatory. A dual-rate camera and measuring machine have been received on loan from the U.S. Naval Observatory for use in the international programme planned for the I.G.Y. No suitable telescope is yet available but some preliminary work has been done on the adaptation of the camera and in the investigation of the measuring machine. The Royal Greenwich Observatory has undertaken to measure the plates taken by similar cameras supplied to the observatories at Canberra, Perth and Wellington, N.Z., but no plates have been received so far.

Astrometry department.—Work was confined to the measurement and reduction of plates taken on the astrographic refractor before it was dismantled. The negatives taken with the astrographic and 26-inch telescopes over the past 60 years were moved from Greenwich to Herstmonceux; some 30,000 glass plates were involved and the operation was carried through, so far as is known, without a casualty.

Equatorial telescopes

30-*inch reflector.*—The newly-figured primary mirror was aluminized in the 38-inch coating plant, which works very well. Undue side constraint on the mirror in its cell was removed by replacing the cork bearers on the inside of the cell by anti-friction pads of 'fluon' (polytrifluorethylene) stuck both to the cell and to the mirror. The instrument was put into use on July 12.

20-*inch reflector.*—A new Cassegrain mirror was made by Messrs Grubb, Parsons & Co. and figured to fit the more suitable of the two primary mirrors. Installation and adjustment were completed by the end of August, when photoelectric observations began.

13-*inch refractor*, 26-*inch refractor*, 28-*inch refractor.*—The main lenses of these, and also the 10-inch and 13-inch (Merz) guider-lenses of the first two, were examined in the laboratory, and colour-focus curves were determined (or re-determined) for all of them. All are in good condition.

Solar department.—The Sun was photographed in white light with the 4-inch photoheliograph on 298 days during 1957. Cape negatives in duplicate have been received up to 1957 September 30. No day is unrepresented in the combined Greenwich–Cape–Kodaikanal series for the year.

Since February one or two additional plates have been taken daily, at intervals of 2 or 3 hours, in connection with the International Geophysical Year scheme for the study of sunspot group development. Positives on film, covering the period 1957 June 16 to 30, have been sent to Zürich.

Measurement of the combined series has been carried up to 1957 April 30, and the copy for press of *Greenwich Photoheliographic Results* for 1956 is in its final stages. Summary tables of mean areas and mean latitudes of sunspots during 1955 have been published in *Monthly Notices.*

On 278 days the Sun was photographed in Hα light with the Levallois-Lyot birefringent filter on the 6-inch Newbegin refracting telescope, and negatives showing disk and limb features have been sent fortnightly to the Fraunhofer Institute for compilation of daily maps.

85 solar flares, including 5 of importance 3, were observed with this instrument or the spectrohelioscopes.

As part of the International Geophysical Year programme, intensive daily flare patrols with the Lyot filter were carried out from June 1 to September 21. Photographs were taken at intervals, not greater than 3 minutes, from 1400 to 1600 hours U.T. Over this period an average coverage of 45 per cent was obtained. Data were transmitted monthly to the appropriate World Centres.

The record of atmospheric noise at a frequency of 27 kc/s showed 194 enhancements (S.E.A.'s) due to the ultra-violet effect of solar flares during daylight hours. A monitor of signal strength tuned to a Paris transmitter (6·2 Mc/s) records fadeouts on the same time-chart, for simultaneity checks.

Current information on solar activity has been distributed to individuals and institutions throughout the year.

Nautical Almanac Office.—The 1958 and 1959 editions of the *Nautical Almanac*, the 1958 editions of the other annual publications of the Office, and the four-monthly parts of the *Air Almanac* for 1957 September to 1958 August have been published during the year. With the 1958 edition, the *Abridged Nautical Almanac* and the *American Nautical Almanac* became identical in content, being produced jointly by the respective Nautical Almanac Offices although printed separately in the two countries; the presentation has been substantially changed, with only minor changes of content. Otherwise no changes of content have been made in the Office publications.

As a result of international agreements, it has been decided that, as from the edition for 1960, the *Nautical Almanac* will be completely unified with the *American Ephemeris*, and the two volumes, although published separately in the two countries, will be produced from identical material. The title will be changed to *The Astronomical Ephemeris*. At the same time the title of the almanac designed for surface navigation, already unified with the American publication, will be changed to *The Nautical Almanac*. The international volume, *Apparent Places of Fundamental Stars*, will be published, as from the edition for 1960, by the Astronomisches Rechen-Institut in Heidelberg.

The volume of *Planetary Co-ordinates for the Years* 1960–1980 and the booklet *Subtabulation* are both in the final stages of printing and should be published in the first half of 1958.

Considerable work was undertaken by the Office in organising and providing prediction services for observers of the artificial satellites launched from the U.S.S.R.

Royal Observatory, Edinburgh

(*Director, Professor H. A. Brück, Astronomer Royal for Scotland*)

Stellar work. 36-in. reflector.—The Observatory's long term spectrophotometric programme has continued. More than 200 spectra of B2–A0 stars have been obtained, and the observational part of the present programme concerning early-type stars is now complete.

The measurement and reduction of spectra of B2 and later B type stars has proceeded. Ninety spectra have been measured in the non-recording microphotometer. The reductions of approximately the same number of spectra have also been completed and, after averaging several spectra for each star, the reduced spectra of about 20 stars have been plotted.

As far as the analysis of the results is concerned, Dr R. Wilson, prior to leaving in April for a year at the Dominion Astrophysical Observatory, Victoria, as a Research Fellow, finished the analysis of the B1 and earlier type stars on which he had been working for many years. His paper in the series on spectrophotometric measurements of the early type stars entitled "Results for stars of type O6–Bo" is in the hands of the printers and will appear in *Publications of the Royal Observatory, Edinburgh*, early in 1958. The paper is particularly concerned with the examination of luminosity effects in He I, He II and C III absorption lines and with He II (4686), N III (4634–42) and C III 5696 emission. An examination of the structure of the emission features shows that in general there is a relatively sharp emission line superimposed on a faint but very extensive broad emission band. The detection of this broad emission band is believed to be new.

The analysis of twenty B2 stars by Dr H. E. Butler and Mr H. Seddon is also complete; their paper is in the hands of the printers and will appear shortly in the series of Edinburgh Publications. In all, equivalent widths of 69 absorption and emission lines have been measured in these stars, and the behaviour of the luminosity effects of the various elements has been examined in detail. Absorption lines of N II, O II and Si III are found to behave almost identically and to show a close (negative) correlation with $H\gamma$ and hence, by Petrie's relation, with absolute magnitude. These lines do not exhibit any emission in the class V stars showing hydrogen emission and hence have certain advantages in assessing the luminosity of these stars. The complex behaviour of the various lines of hydrogen and neutral helium with luminosity is demonstrated. In addition to Mg II (4481) previously reported, the absorption lines of Si II and C II are shown to be relatively insensitive to luminosity. Real and incipient emission in H, He I, He II, Fe II, Mg II and C II is examined.

Intensity measures are given of numerous interstellar lines. Plots appear to show the presence of a possible new interstellar band at 4890 A.

The paper includes a large scale atlas of three averaged spectra, representative respectively of B2 supergiant, dwarf and dwarf-with-hydrogen-emission stars.

It is anticipated that the measurement, reduction and analysis of twenty-five B3 stars will be completed during the year, and that the additional analysis of a small number of B5 and Ao stars will complete the present spectrophotometric programme.

16-in. *Schmidt telescope.*— Dr V. C. Reddish and Mr J. H. Reid have continued their work on galactic clusters and have completed observations on NGC 6940 in three colours (B, V, R). Observations on NGC 1245 are nearing completion. Altogether 34 plates on clusters and standard regions have been obtained during the year, most with exposures between half an hour and an hour, some with two hours, reaching to about the seventeenth magnitude.

Solar work.—Disk drawings of the Sun in white light were obtained on 163 days, and Hα observations were made with the spectrohelioscope on 169 days. I.G.Y. flare patrols were carried out from July 1 on all fine days (11^h00^m–13^h00^m in winter, 13^h00^m–15^h00^m in summer). Fifty-seven flares were recorded

during 274 hours of observation: 4 of class 3, 14 of class 2, 27 of class 1 and 12 of class 1⁻. Flare development curves of the Hα line-width versus time were plotted whenever conditions permitted.

The year was a record one for solar activity, judged by the Zürich relative sunspot numbers (*R*). The monthly means of the (provisional) *R*-values for September (244) and October (263) were the highest recorded since the series began in 1749. The high level of flare activity is, likewise, shown by the large number of sudden ionospheric disturbances recorded in Edinburgh during daylight hours. The recorder which gives the integrated level of radio atmospherics on a frequency of 24 Kc/s has been in continuous operation; the number of sudden enhancements of atmospherics (206) may be compared with those of previous years as follows:

Year	1950	1951	1952	1953	1954	1955	1956	1957
S.E.A's	82	81	22	7	0	33	107	206

A similar radio receiver, recording atmospherics on a frequency of 30 Kc/s, has been in use since the beginning of the I.G.Y.

The short-wave receiver, recording cosmic radio noise on a frequency of 18 Mc/s, has been in operation throughout the year: sixty-seven sudden fade-outs of cosmic noise (S.C.A's) have been recorded with this set.

A direct recording H-magnetograph, constructed by Askania-Werke A.G., was brought into use in October. This instrument, in which the magnet deflection is converted by a split photocell into current, has the advantage over photographic recording that it supplies immediate visual evidence of the occurrence of 'crochets' and of the onset of magnetic storms. It has been calibrated in γ by reference to Eskdalemuir magnetograms.

Dr M. A. Ellison paid visits in April and November to the firm of S.E.C.A.S.I. in Bordeaux, where the Lyot-type Hα heliograph has been under construction. The contract had been placed by the Admiralty, acting on behalf of the British National Committee for the I.G.Y., in 1955 December, and the completed instrument was accepted at Bordeaux on 1957 November 26. It will be erected early in 1958 under Dr Ellison's supervision in the housing specially prepared for it at the Royal Observatory, Cape of Good Hope.

A paper on "The Spectrum of Quiescent Prominences" by Dr M. A. Ellison and Mr J. H. Reid appeared during the year as Vol. II, No. 2 of the Edinburgh Publications. The contents of this paper are summarized in *M.N.*, **116**, 699, 1956.

Other work.—Dr Reddish has contributed papers on the ejection of matter by red giant components of close binaries (*The Observatory*, **77**, 202, 1957) and composite colour-magnitude arrays of Population I (*The Observatory*, **77**, 235, 1957). He has continued his investigations into the physical evolution of the Galaxy.

Mr H. Seddon has been engaged on the design and construction of a photo-electric spectrophotometer for use on the 36-in. reflector. A completely electronic ratiometer has been evolved in which the reference quantity may vary over a range of at least 10^3 and the ratio appears directly as a meter reading. The time constant is much smaller than in the standard methods. The reference photomultiplier is operated in a restricted range of wave-lengths centred on the region under investigation.

Time-service.—The mean-time clock Riefler 258 has been in use throughout the year to provide the control currents for the Edinburgh clocks, time-gun and time-ball.

Seismology.—Our thanks are due, as in former years, to Mr E. Tillotson for undertaking the reduction of the Milne-Shaw seismograms and for answering correspondence relating to them.

Staff.—Professor Brück was appointed Astronomer Royal for Scotland and Professor of Astronomy in the University of Edinburgh on February 12 and took up duties on September 1.

There have been two promotions, and the scientific staff consists now of Drs H. E. Butler and M. A. Ellison as Principal Scientific Officers, Dr R. Wilson and Mr H. Seddon as Senior Scientific Officers, Mr J. Reid as Experimental Officer and Mr G. A. Ramsden as Assistant Experimental Officer. Dr V. C. Reddish has been attached to the staff in his capacity as Lecturer in the University Department of Astronomy which is housed at the Observatory.

Royal Observatory, Cape of Good Hope

(*Director, Professor R. H. Stoy, C.B.E., H.M. Astronomer*)

Gill Reversible Transit Circle.—The observations for the "Second Cape Catalogue for 1950.0" were continued. The working list contains approximately 7000 stars and many of them have now received their full quota of eight observations, four in each position of the instrument. It is hoped that the observations for the remainder will be completed during 1958.

During 1957, a total of 8985 transits was observed. This includes 340 observations of stars during the day time and the following observations of bodies in the solar system:—

Sun	122	Jupiter	20	Ceres	1
Moon	28	Saturn	16	Pallas	14
Mercury	53	Uranus	21	Juno	8
Venus	103	Neptune	18	Vesta	15

The preparation of the next working list is in hand. It will be in five sections, the first section containing stars from the fundamental catalogues south of 30° N and the other sections relatively faint stars between −30° and −40°, −40° and −52°, −52° and −64°, −64° and −90°, specially selected to serve as standards in the reduction of photographic plates. The resulting catalogue is intended to form a southern extension of similar catalogues being prepared in the northern hemisphere.

Cape Photographic Catalogue for 1950.0.—Work on this project proceeds steadily, the position at the end of 1957 being as follows: the catalogue was published as far as −56°; ready for publication to −64°; positional measures complete to −72°; photometric measures complete to −68°. About one third of the photometric plates for the zone −68° to −72° and one half of the astrometric plates for the zone −72° to −76° were measured. South of −76° the meridian and photographic observations are complete and the stars to be measured have been selected. The computation of the necessary standard coordinates is in hand.

Minor planets.—The routine observation at approximately ten day intervals of ten selected minor planets has been continued. This is the programme suggested by the Russian astronomers for using such observations to control systematic errors in star catalogues. During 1957 the following observations were obtained:—

1. Ceres	0	4. Vesta	13	18. Melpomene	6
2. Pallas	12	6. Hebe	13	39. Laetitia	9
3. Juno	7	7. Iris	14	40. Harmonia	0
		11. Parthenope	12		

Photoelectric photometry.—During 1957 the photoelectric photometer attached to the Victoria 24-inch refractor was used on 92 nights to make 2198 three-colour observations for the general programme, which includes all Johnson stars south of 10° N, the stars being observed for radial velocity, the H.D. stars in the Cape parallax list which have not already been observed photoelectrically, and other stars of special interest which have been included at the request of various astronomers. By the end of the year magnitudes and colours had been derived for over 250 programme stars, all of which had been observed at least four times.

The same photometer was used on 47 nights to make 1123 three-colour observations for the main E region programme. This programme, which was planned to consolidate the work on the brighter standard stars in the nine E regions is now virtually complete down to the eleventh magnitude for all the regions except E 7 which will require further observations during 1958. 408 three-colour observations were made in E 4–E 9 for the complementary programme with the Cassegrain photometer attached to the Radcliffe reflector.

All the data referring to the brighter stars in the E regions have been re-examined and a mimeogram prepared giving magnitudes and colours for 264 stars brighter than 8·7 SPg for which blue and yellow magnitudes have been observed in at least three independent series of precision observations. The mimeogram gives *V*, S′Pg and SPv magnitudes and the *B–V*, S′CI and Cape U–B colours. *V* and *B–V* are intended to be on the Johnson–Morgan system while S′Pg and S′CI are slightly modified versions of the 1953 SPg and SCI obtained by eliminating the effect of ultraviolet radiation with a filter of Schott GG 13 glass. The Cape U–B colours refer to a "refractor" ultra-violet, blue system and so differ fairly considerably from the Johnson–Morgan *U–B* system which was established with aluminised reflectors.

The 18-inch reflector and its photoelectric photometer were completed in March. After some experimental observations to investigate the effect of various filters, the instrument was brought into regular use for two programmes, the first the observation of E region stars brighter than 10·0 SPg for which the existing data are weak, and the second the observation of magnitude sequences near certain bright cepheid variable stars. A third programme could not be started until the end of the year because of the lack of suitable filters. This is the observation of the brighter southern stars as closely as possible on the Johnson–Morgan *U*, *B*, *V* system by comparing them directly with standard stars near the equator. The 18-inch reflector was used on 70 nights during 1957 and 2170 observations were made with it.

The photoelectric photometer attached to the Astrographic refractor was used for the programme which includes all the stars in the Yale Bright Star Catalogue between −4° and −64°, but relatively little progress was made in

1957 because of the poor weather, shortage of observers, the reconditioning of the telescope and its preparation for use during the I.G.Y. with the Markowitz dual rate lunar camera. Attention was concentrated on completing the blue-yellow observations for stars that had already been observed in these colours, since it is hoped to make most future observations in three colours. By the end of 1957, magnitudes and colours had been derived for over 1400 programme stars, all of which had been observed at least four times. Towards the end of the year a start was made with measuring ultraviolet-blue colours for those stars that had already been observed in the blue and yellow. Priority is being given to the stars in the E regions, to the brighter stars and to stars of type F and earlier. During 1957 the Astrographic refractor was used on 19 nights to obtain 479 observations for the B, Y programme and on 20 nights to obtain 481 observations for the U, B programmes.

The Astrographic refractor and photometer were also used on 24 nights by Mr R. V. Willstrop of the Cambridge University Observatories to determine "narrow band" magnitudes for a number of bright stars. He made 1141 observations using interference filters that had been selected as a result of experience with the three-colour photometer at Cambridge. Their peak transmissions are at 4180 A, 4375 A, 4584 A and 5405 A and the half widths of their transmission bands are about 100 A. As compared with known V magnitudes, the 5405 A magnitudes show a r.m.s. scatter of $\pm 0{\cdot}026$ magnitudes but no colour equation. The other filters yield magnitudes which, when compared with the B magnitudes, give non-linear colour equations and a r.m.s. scatter of about $\pm 0{\cdot}03$ magnitudes. These scatters are, of course, much larger than can be attributed to errors of observation.

The observations with the Astrographic refractor are subsidiary to Mr Willstrop's main programme which is to be carried out with the same filters, but used in a photometer attached to a 4-inch telescope that was constructed at Cambridge and which has been mounted in the Wind Tower. With this he plans to compare the bright stars with each other and with standard lamps mounted in the turret of the main building. These standard lamps have been calibrated for colour temperature and brightness at the National Physical Laboratory and it is hoped to transfer these calibrations to the stars and thus evaluate the conventional system of magnitudes and colours in terms of ordinary physical units.

Photographic photometry.—The photometric cameras attached to the Astrographic refractor were used to obtain the 26 pairs of plates needed to complete the $-68°$ to $-72°$ zone programme and the programme comparing the selected areas at $+15°$ with the standard E regions at $-45°$. 51 560 images were measured with the modified Schilt Photometer. This completed the measurement of the selected area, E region programme, the $-64°$ to $-68°$ zone programme and one third of the $-68°$ to $-72°$ zone programme.

Variable stars.—Mr R. P. de Kock continued the programme of observing long period variable stars which he began twenty-five years ago. During 1957 he made 6082 observations of 174 stars with the 6-inch telescope. He also kept a special watch on T Orionis and on two "flare" stars 013418 UV Ceti and 203501 AE Aquarii.

Thirty-two pairs of plates were taken with the Victoria telescope for Dr Arp's programme on the long period variables in the two globular clusters Omega

Centauri and 47 Tucanae. The plates were taken at approximately ten-day intervals.

Radcliffe section.—Most of the observing time with the Radcliffe reflector available to the Cape during 1957 was used for radial velocity observations; about half for the Cape programme of nearby stars and stars of large proper motion; and the remainder for the Greenwich programme of 120 stars in the region of the Southern Galactic Cap, so selected that their magnitudes range from 5·5 to 9·0 and their HD type from A0 to A5. The aim of the Greenwich programme is to determine whether the fainter stars have a higher average velocity in the direction perpendicular to the galactic plane than do the brighter and thus to test whether a single distribution of velocities can represent the Z motions of the A stars. 962 spectra were obtained of which 366 were for Greenwich. Some of the remainder were of MK stars and were intended to provide convenient standards for spectral classification. 915 spectra were measured for radial velocity, and spectral types on the MK system were estimated for the programme stars as the plates became available. The spectra of nine planetary nebulae were also measured and discussed.

An account of the first Cape radial velocity programme with the Radcliffe reflector was prepared and the results combined with photometric observations made at the Cape to give fundamental data for a selection of about 340 southern stars. Photometric parallaxes, space coordinates and space motions were deduced for 142 Class V stars of type F3 and later.

Besides the radial velocity work, 29 Newtonian plates of extragalactic nebulae were taken and 408 observations were made with the Cassegrain photoelectric photometer. The first section of the *Cape Photographic Atlas of Southern Galaxies* was produced during the year. It consists of enlarged prints from 24 selected plates, each of which is accompanied by a short description. The enlargements have been made by a local professional photographer and the *Atlas* is being sold at cost.

Miscellaneous.—The Sun was photographed on 333 days, two photographs being taken each day except two. All the photographic plates have been sent to Herstmonceux for measurement. 50 observations of 28 occultations were made with the various telescopes at the Observatory. Of these 47 were disappearances at the dark limb, 2 reappearances at the dark limb and 1 a disappearance at the dark limb. A "Moonwatch" station for the observation of artificial satellites has been established at the Observatory and is manned by capable volunteers.

Armagh Observatory

(*Director, Dr E. M. Lindsay*)

Dr Öpik spent the first five months of the year as Visiting Professor at the University of Maryland where he conducted a postgraduate course on "The Physics of Meteors and their Cosmic Relationships" and addressed various scientific societies and bodies. Both there and at Armagh he continued his researches on the physical theory of meteor phenomena and their bearing on rocket and satellite research.

Dr Lindsay returned from the Boyden Observatory at the end of January. Research had been mainly on the photographic and photoelectric material obtained

at the Boyden Observatory during the previous six months. The cluster survey of the Small Magellanic Cloud was completed. A catalogue of 116 objects which are considered to be cluster members of the Cloud was prepared, together with approximate dimensions, positions and magnitudes. The search for further emission objects in the Small Cloud has been completed. This has led to the discovery of a large number of new objects; the final list will contain between six and seven hundred emission objects. Good progress has been made in measuring the magnitudes of these using the Iris Diaphragm Photometer.

Photographs of Comets Arend-Roland and Mrkos were obtained by Dr Lindsay and Mr Grossie with the Armagh Schmidt telescope. The variable star programme was continued with this instrument but unusually bad weather together with two unsatisfactory lots of photographic plates considerably curtailed the programme.

Observations of artificial satellites 1957 Alpha and 1957 Beta were made regularly by the Observatory staff. Dr Öpik worked out a method of prediction of appearances.

The meteorological observations were continued by Miss Grew.

Contributions Nos. 18–20 and Leaflet No. 45 have been distributed. Contributions Nos. 20–22 have been published: No. 20, "The Dimensions of Omega Centauri" by E. M. Lindsay (*Vistas in Astronomy*, Vol. **2**, p. 1057, Pergamon Press, London and New York, 1956); No. 21, "A Catalogue of Stellar-like Emission Objects in the Small Magellanic Cloud" by E. M. Lindsay (*M.N.*, **116**, 649, 1956); and No. 22, "The Photoelectric Light Curve of V499 Sco" by G. G. Cillié and E. M. Lindsay (*M.N.*, **117**, 445, 1957) with Appendix "Individual Observations of V499 Scorpii" (published by the Armagh Observatory, 1957). Leaflets Nos. 45–47 have been published: No. 45, "Armagh Observatory in 1956" by E. M. Lindsay (*I.A.J.*, **4**, 137, 1957); No. 46, "The Density of the Lunar Atmosphere" by E. J. Öpik (*I.A.J.*, **4**, 186, 1957); and No. 47, "Artificial Satellites" and "Comments on Satellites" by E. J. Öpik (*I.A.J.*, **4**, 201 and 252, 1957).

Other publications were: "Ice Ages" by E. J. Öpik (Chapter Ten in "The Planet Earth", D. R. Bates, Pergamon Press, London and New York, 1957); and "The Age of the Earth and the Universe" by E. J. Öpik (*Discovery*, 1957, p. 487).

A text book on "The Physics of Meteor Flight in the Atmosphere" by E. J. Öpik has been prepared for print and is in the course of publication. A paper on "The Cluster System of the Small Magellanic Cloud" by E. M. Lindsay has been accepted for publication in the *Monthly Notices*.

Dr Öpik participated in meetings on November 5 and 6 called by the Royal Society for the discussion of the methods of observation and prediction of artificial satellites. Dr Lindsay attended a meeting of the Boyden Observatory Council held in Brussels on June 11 and 12.

Cambridge Observatories

(*Director, Professor R. O. Redman, F.R.S.*)

Solar Research.—On April 1 a second balloon flight similar to that mentioned in last year's Report, was made from the Meudon Observatory, by Dr Blackwell and Dr A Dollfus (Meudon), with the cooperation of Dr Dewhirst. The solar

granulation was successfully photographed at heights between 15 000 and 20 000 ft, the best frames showing detail down to about 0·4 sec of arc, which is near the resolution limit of the 11-inch objective. Photometric measurements of the granulation are now being analysed. Thanks are due to the Director of the Paris Observatory for permission to use the facilities of the Meudon Observatory. The work was supported by a Royal Society Government Grant.

Construction has been continued on the solar magnetograph and associated equipment, including the scanning mechanism and a photoelectric guiding arrangement.

Dr von Klüber has completed the photometric and polarimetric investigation of the corona mentioned in the last Report, and a paper has been submitted to the Society. Plans are well advanced for an expedition, supported by the Royal Society, to observe the total solar eclipse of 1958 October 12 from a Pacific island, probably Atafu. The chief purpose is to make interferometric measurements of the green and red coronal lines. Dr von Klüber will be accompanied by Mrs von Klüber and Dr A. H. Jarrett (St. Andrews University Observatory). Dr and Mrs von Klüber have also made a thorough reconnaissance of the Canary Islands in connection with the total solar eclipse of 1959 October 2. A report has been circulated to the J.P.E.C. and I.A.U. Commission 13.

Dr Thompson has measured the profiles of a number of weak to moderately strong Fraunhofer lines at various places between centre and limb of the Sun, using the large Babcock grating. He has also begun an examination of the ultraviolet chromospheric spectrum on photographs made by Dr Dewhirst at the 1954 eclipse, chiefly to try to deduce the electron temperature from the Balmer discontinuity by Zanstra's method. Preliminary results suggest that an appreciable amount of Rayleigh scattering must be taken into account.

Dr Blackwell has studied the relation between zodiacal light data and theories of interplanetary gas. He has concluded that the weight of evidence is at present against the existence of such a gas in the concentration hitherto accepted. With the help of a grant from the Royal Society he is preparing an expedition to the Cosmic Ray Observatory of Chacaltaya in the Andes (altitude about 18 000 ft) with the object of collecting better optical data on the zodiacal light.

His recent work on the outer corona and zodiacal light has led Dr Blackwell to measure, with the help of Mr R. V. Willstrop, the polarization of light from Comet Arend-Roland (1956h) on the light of 3800 A CN band and in the continuous spectrum. A paper has been communicated to the Society. The results are expected to be of use later in interpreting zodiacal light measures.

17-inch Schmidt telescope.—Mr Argue has continued his critical study of the problem of in-focus stellar photometry with a Schmidt telescope. Making measurements in Becker's RGU system he finds the (internal) standard error of one measurement of one star image varies in the best conditions from $0^{m}{\cdot}04$ at 6^{m} to $0^{m}{\cdot}10$ at 15^{m}, for U or G images, with R images giving errors 10 to 20 per cent greater. A technique for reducing such measures with an electronic computer (EDSAC) is being worked out. So far, the results suggest that a 3-colour system, with the accuracy practicable in in-focus photographic photometry, is not in general sufficient to do all that one desires in segregating stars of different intrinsic luminosity and in distinguishing between intrinsic redness and reddening by interstellar matter. Other matters examined during the course of this work include field errors, and the effect of ghost images, of flat glass

filters of finite thickness, and of guiding errors in long exposures. Mr Argue has also measured mechanical flexure as it affects the relative positions of mirror, correcting plate and photographic plate in this telescope, and has concluded that in practical cases it should have a negligible effect on in-focus stellar photometry.

Comets 1956h and 1957d were photographed with this telescope by Mr Argue and Mr N. J. Woolf (Manchester University Astronomical Department) using interference filters with a half width of 50 A, centred on 4265 A. The purpose was to measure the distribution of CO^+ radiation in the comet tail. The CO^+ intensity in Comet 1956h was disappointingly low.

36-inch reflector.—Dr Fellgett has completed his multiplex interferometric spectrometer and has used it at the coudé focus of the 36-inch reflector to measure infra-red stellar spectra. Fringe intensities have been recorded for a number of stars down to 8^m and Fourier transforms of the measures have yielded the required spectra. The expected sensitivity was reached and a resolving power of about 25 was attained. Further progress in this technique will require better guiding arrangements and improved control of the path length difference in the interferometer. As with all infra-red work in England, water vapour absorption is a serious hindrance.

The new spectrometer designed by Mr Willstrop has been completed and used by him in a 3-colour photoelectric photometry designed to elucidate the physical meaning of conventional magnitude systems. Both Ipv, Ipg and *U*, *B*, *V* systems can be mimicked closely by quasi-monochromatic measures in suitably chosen pass bands, 200 A wide. Mr Willstrop has prepared photometric equipment for a further development of this work and has taken it to the Royal Observatory, Cape of Good Hope, where observations will be made in more favourable sky conditions than are obtainable at Cambridge.

Professor Redman and Mr Griffin have since modified the spectrometer to measure three adjacent regions, each 50 A wide, the middle one on the 4200 CN band. Three independent photomultipliers are used simultaneously, with pulse counting circuits. Simultaneous measurement of the three bands is essential, owing to variable scintillation losses at the slit, even though this is 2·5 sec of arc wide. On an average Cambridge night it appears possible to measure K type stars to 7^m in one minute, with a relative accuracy of about one per cent, even though the sky may be poor for conventional stellar photometry. The average zenith extinction at Cambridge in this region of the spectrum is very high; a site with good transparency and reasonably good scintillation would probably allow measures to be taken at least 1^m further, without any modification of the apparatus. The method could be applied to other important features of stellar spectra.

Optics.—Dr Linfoot has obtained simple general formulae for the centring tolerances in optical systems of the types normally used in large telescopes, in terms of the acceptable coma of the ray-theoretic image. These formulae are of importance for the mechanical design of mirror mountings and of telescope tubes, and in estimating the relative practical merits of different designs for large telescopes.

An 8-inch chromium plated steel mirror has been polished from a precision ground surface and figured to a little better than $\pm\frac{1}{4}$ fringe. This proved to be a very slow process and surface scatter from the chromium layer remains

appreciable. Thin glass cemented to steel appears to give a better means of obtaining thermally stable coelostat mirrors.

A corrector plate for an 8-inch *f*/0·8 Schmidt spectrograph camera has been completed by Mr M. F. Ingham under Dr Linfoot's supervision. The work has been carried out with the aid of a D.S.I.R. grant. The spectrograph is to be used by the zodiacal light expedition mentioned earlier.

Other investigations.—With the kind cooperation of Dr A. D. Thackeray a programme of measurement of Hγ intensities in southern B-type stars has been commenced by Dr Beer, using spectrograms from the Radcliffe Observatory, Pretoria. The object is to estimate absolute magnitude by Petrie's method. The results should form a valuable supplement to other work on these stars now in progress at Pretoria.

In collaboration with Dr Wu-Shih-Chang (Oxford) and Professor W. Hartner (Frankfurt), Dr Beer has examined two Chinese oracle-bone inscriptions, date about 1300 B.C., which may refer to the appearance of a bright supernova near Antares. An identification for this supposed supernova has been sought among radio sources and peculiar optical objects.

Newall telescope.—The Newall 24-inch refractor has been presented to the Athens Observatory. It was dismantled and packed by Messrs Grubb, Parsons, Ltd and was sent to Athens in May. The dome and its annexes had reached the end of their useful life and have been demolished.

Colloquia.—The Observatory Club held 12 colloquia during the year. Speakers from outside Cambridge included Professor J. Neyman (Berkeley), Professor M. Minnaert (Utrecht), Dr A. D. Thackeray (Pretoria), Miss M. G. Adam (Oxford) and Dr B. J. Pagel (Herstmonceux).

Cavendish Laboratory, Mullard Radio Astronomy Observatory
(*Director, Professor N. F. Mott, F.R.S.*)

1. *New equipment.*—On 1957 July 25, the Mullard Observatory was formally opened by Sir Edward Appleton. Good progress has since been maintained in the completion of the two large instruments (**1**). One of these, a 3 300 ft E–W array at a wavelength of 7·9 m used in conjunction with a movable element, is already in operation. It is being used to carry out a survey of the galactic structure with an angular resolution of about $1^\circ \times 1^\circ$.

The other major instrument, the radio star interferometer for use at a wavelength of 1·7 m, would also have been operating had it not sustained some damage in a severe 90 mph gale in November during its erection. It is hoped to commence observations with this radio telescope during the summer.

In addition to the two large instruments, some high-resolution interferometers are in use for solar observations as described below.

2. *Solar observations*

(*a*) *The outer corona.*—In view of the increasing difficulty of observing the occultation of the Crab nebula caused by intense emission from regions of solar activity, extensive experiments were not carried out in 1957. A series of measurements was, however, made at 1·9 m and these indicated that the tendency of the coronal irregularities to become more pronounced toward sunspot maximum was maintained, the observed scattering being considerably greater than in 1956.

(*b*) *Active regions.*—High resolution interferometers have been set up at the Mullard Observatory with their axes along E–W and N–S directions. These are being used to investigate the instantaneous positions and sizes of the short duration radio bursts which occur during noise storms.

(*c*) *Routine observations.*—As part of the I.G.Y. programme regular observations have been maintained of the intensity of the solar radio emission on wavelength of 3·7 m and 1·7 m.

3. *Radio stars*

(*a*) 159 *Mc/s survey.*—Two separate sets of observations have been made using the four-aerial interferometer at a frequency of 159 Mc/s. These have the object of determining (i) positions and flux densities, and (ii) angular diameters of radio stars. Positional data for 450 sources with flux densities greater than $8 \cdot 10^{-26}$ w.m.$^{-2}$ (c/s)$^{-1}$ have been extracted from the records. These positions are being examined by D. W. Dewhirst of the Cambridge Observatories, at present at the Mount Wilson and Palomar Observatories, for optical identifications. A comparison between these new positions and those found by Mills and Slee at 85 Mc/s show fair agreement among the brighter sources but poor agreement among the weaker ones. Few sources away from the plane were found to have angular diameters greater than a few minutes of arc.

The aerial has also been used as a "crossed axis" interferometer to determine independently the positions of 15 of the brightest sources (**2**).

The evidence on the spatial distribution of radio sources derived from the new survey has been considered (**3**) both by number counts and a statistical method (**4**) which avoids possible errors due to confusion. Although the statistical significance of the present results is not as great as could be desired they support the earlier conclusions (**5**) that there is a deficit of intense sources as compared with the number of weak ones.

(*b*) *Supernovae.*—Special measurements have been made with the four-aerial interferometer at a frequency of 159 Mc/s to obtain accurate positions and angular diameters of the radio sources close to the positions of the supernovae of AD 1572 and 1604 (**6**). The identifications are confirmed although the angular diameter of Tycho's Nova is much greater than expected. The surface brightness of these sources and that of the Crab nebula are found to differ widely.

(*c*) *The spectra of radio stars.*—Data on the spectra of radio stars, which might be of value in distinguishing different classes of source, are very limited. Flux density measurements over a wide range of frequencies are required for this reason. Conway (**7**) has measured the flux densities, relative to that of Cygnus A, of eleven sources at 500 Mc/s. Whitfield (**8**) has made measurements at 38 Mc/s and has collated this and all other available flux density data to derive the spectra of 31 sources. He finds systematic differences between the spectra of galactic and extra-galactic sources.

4. *Earth Satellites.*—Signals from the Russian Earth Satellite 1957α were received on October 5 at 40 Mc/s and a special interferometer was set up for tracking purposes (**9**). The results were forwarded to the Nautical Almanac Office together with ranges determined from the rate of change of received frequency. A provisional orbit was computed for October 15.0 and predictions were provided for various optical and radar observatories. Signals were also recorded at 20 Mc/s and 80 Mc/s and these are at present being studied by the

ionosphere group in the Cavendish Laboratory. The periodic fluctuations of the signals due to the Faraday rotation in the ionosphere have been shown to be consistent with the model ionosphere derived from pulse-sounding techniques.

Observations were also made of 1957β but all further observations will be carried out by the ionosphere group of the Laboratory.

5. *Comet Arend-Roland.*—Observations were made during the period March 12–May 13 on frequencies of 38 and 81·5 Mc/s in an unsuccessful attempt to detect radio emission from the Comet Arend-Roland (**10**). The upper limit of the flux density derived from these measurements was considerably less than the values reported by other workers at 27·6 Mc/s and 600 Mc/s.

Observations of the scattering of radiation from radio stars viewed through the comet tail placed an upper limit of 10^4 on the root-mean-square departure from the mean value of the electron density in the tail.

6. *Galactic investigations*

(*a*) Observations to detect linear polarization of the radio emission from the galaxy have been made by Thomson (**11**) at a wavelength of 1·9 m using a pair of crossed dipoles at the focus of a 7·5 m paraboloid. In two regions of the sky a polarized component about 1 per cent of the total radiation may have been observed.

(*b*) The supposition that the galactic radio emission arises from the acceleration of relativistic electrons in interstellar magnetic fields has been used by Tunmer (**12**) in an explanation of the remarkable and intense feature of the background radiation extending from the galactic plane near $l=0°$ towards the north galactic pole. It is suggested that the radiation is due entirely to electrons within the local spiral arm.

(*c*) The survey of the galactic radiation at a wavelength of 7·9 m by Blythe has now been published (**13**, **14**).

(*d*) A survey of the galactic radiation at a wavelength of 1·9 m, using one section of the four-element radio telescope, is in progress.

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University Observatory, Glasgow
(*Director, Professor W. M. Smart*)

Dr M. W. Ovenden has examined the relationship of the radial velocities of stars of spectral types Ko–M, as given in Wilson's *General Catalogue of Radial*

Velocities, to the two-streams theory. In particular, a method has been derived whereby, assuming the drift apices and the values of h_1W_1 and h_2W_2 from a proper motion analysis, the radial velocities can yield values for h_1 and h_2 and the partition of the stars between the two drifts. An application of this method to the radial velocities of late-type stars gives essentially equal values for h_1 and h_2 ($=0{\cdot}0386$ sec km^{-1}), with 56·5 per cent of the stars in drift I. An account of this work appeared in *M.N.*, **117**, 629, 1957.

During the year, an analysis was begun of the proper motions of the *General Catalogue* according to a generalized ellipsoidal theory relating to the systematic motions of the stars. However, progress in assembling the data in the required form was slow.

Dr T. R. Tannahill resigned on 1957 September 30, and his successor had not been appointed when the year ended.

University of London Observatory

(*Director, Professor C. W. Allen*)

Laboratory spectroscopy.—In order to extend and check the method of measuring oscillator strengths by the use of arc spectra of diluted copper alloys, the Director has made some measurements of Li, Na, Mg, and Ca lines. Li and Na were found unsatisfactory, but a table of absolute oscillator strength measurements for Mg and Ca has been obtained. Earlier *f*-values in Ga, Ag, Sn, Pb, and Bi have been revised.

Use of telescopes.—The Radcliffe 24-inch refractor was used on 9 nights for photography of Comet Arend-Roland, 6 nights for photo-electric observations of spectroscopic binaries, and 6 nights for photography of selected areas. 12 comet plates were measured and reduced for position.

Instrument construction.—Two spectrographs intended for oscillator strength work have been constructed and are nearly ready for use. One, set by up J. B. Tatum, contains sets of Hilger quartz and glass optical trains. The other is a vertical stigmatic plane grating spectrograph with a Jarrell mounting. Photo-electric recording equipment for use with this spectrograph has been developed and tested by Mr E. W. Foster.

Theoretical work and analysis.—Dr P. A. Sweet's cosmical electromagnetic studies have led to theories of the production of high energy particles in solar flares. He has also studied the application of topological methods to magnetic fields, and has shown that the lines of force of a given force-free magnetic field confined within a bounded region of space lie on a unique family of tori. Dr R. H. Garstang completed his calculations on transition probabilities of forbidden lines in the ground configurations of Fe III and Fe V. Work was begun on forbidden lines in the $3d^9$ and $3d^84s$ configurations of Ni II, methods being developed for general application to transitions of the form $d^n - d^{n-1}s$. A study of radial quadrupole integrals in atoms of the first long period was made and the results used both to revise earlier calculations on [Ni III] and to provide necessary data for the [Ni II] calculations. A general survey was made of atomic data of interest for the study of emission line stars. Mr T. Kiang has made a study of the effect of the seasonal factor on the distribution of nodes and perihelia of the minor planets.

Publications.—The following papers have been published during the year:

C. W. Allen, " Spectrophotometry of the outer corona ", *M.N.*, **116**, 413, 1956.
C. W. Allen, " The quiet and active Sun ", I.A.U. Symposium No. 4 on *Radio Astronomy*, p. 253, 1956.
C. W. Allen, " The variation of decimetre-wave radiation with solar activity ", *M.N.*, **117**, 174, 1957.
C. W. Allen and A. S. Asaad, " Oscillator strengths from arc spectra of diluted copper alloys ", *M.N.*, **117**, 36, 1957.
R. H. Garstang, " The computation of quadrupole line strengths ", *Proc. Camb. Phil. Soc.*, **53**, 214, 1957.
R. H. Garstang, " Transition Probabilities for Forbidden Lines of Fe III and Fe V ", *M.N.*, **117**, 393, 1957.
R. H. Garstang, " Positions of Comet Arend-Roland (1956h) ", *M.N.*, **117**, 505, 1957.
University of London Observatory, " Stellar parallaxes determined at U.L.O.", *M.N.*, **116**, 267, 1956.

Staff, students, and visitors.—There have been no staff changes. Dr P. A. Sweet left in September for a year in the Astronomical Department at Berkeley. Two postgraduate students, Mr J. B. Tatum and Mr J. S. Griffith, began work in October. Nine undergraduate students have been taking regular lecture courses since October. Drs M. Minnaert and B. Pagel have been visiting speakers to the Observatory colloquia and there have been 477 afternoon and evening visitors.

Royal Radar Establishment, Ministry of Supply, Malvern

The steerable radio telescope with an aperture of 45 ft diameter was completed in early 1957. This radio telescope has a parabolic reflector which has been constructed with sufficient accuracy for use at wavelengths down to 10 cm. In Great Britain, there has been comparatively little radio-astronomical research at centimetric wavelengths, and it was therefore considered desirable that the new radio telescope should be designed for operation at these short wavelengths.

The construction and erection of the 45 ft aluminium reflector was completed within a year by Precision Metal Spinnings (Stratford-on-Avon) Ltd., according to a design prepared by the consultants, Messrs Jenkins and Potter Ltd. The reflector was fitted to an old radar turning mechanism, mounted on a tower constructed by the Military Engineering Experimental Establishment of the Ministry of Supply.

It was originally intended that the telescope should first be used to pursue the detection of the radio spectral line at 91 cm wavelength from deuterium in the galaxy. Measurements were about to commence in October 1957 when the first Russian Earth satellite was launched. It was then decided to suspend the deuterium line experiment temporarily in order to fit a radar transmitter at 10 cm wavelength into the radio telescope for radar observation of the satellites. This equipment has also been used for radar observation of the Moon, and preliminary observations have been described in *Nature*, **180**, 1225, 1957. The transmitter has a peak power of 2 megawatts and a pulse length of 5 microseconds which makes it possible to measure distances with an accuracy of about 1 km.

Jodrell Bank Experimental Station, University of Manchester

(*Director, Professor A. C. B. Lovell, F.R.S.*)

The radio telescope.—As anticipated in the last report the 250 ft steerable radio telescope was brought into operation during the summer of 1957. The first records of the galactic and extra-galactic radio emissions were obtained in early August. These initial tests were mainly concerned with an assessment of the performance of the telescope on frequencies of 160 and 408 Mc/s. The beam width and power gain were found to be close to the predicted values at these frequencies and the general performance of the telescope met all expectations. The initiation of the astronomical research programme on these and other frequencies was delayed during the rest of the year by the completion of minor engineering tasks and by the use of the telescope as a radar instrument to study the Russian Earth satellites and carrier rockets. This work was carried out on frequencies of 36 and 120 Mc/s and interesting information was obtained about the extent of the confusion of the echoes with meteor and auroral radio echoes at these high power densities, and the complex fading of the echoes (**1, 2**).

Galactic and extragalactic radio emissions.—(i) *92 Mc/s survey.*—The 92 Mc/s interferometer survey has been extended to cover the region of sky already covered by the 92 Mc/s total power survey. The sensitivity of the survey is such that over much of the region the analysis of observations is limited by confusion. The analysis has now been completed and the results compared with the total power observations. Serious differences were noted between the two surveys and these have been attributed to confusion effects.

A detailed comparison has been made between the total power and interferometer observations and the results used to estimate the limit of reliability of a radio source survey which is confusion limited. It has been shown that confusion effects are more serious than had previously been considered, and that serious errors are likely to occur in radio source surveys when the observed density of sources reaches a level of about one per twenty-five beam areas.

(ii) *Diameter of the radio stars.*—Measurements of the angular distribution of intensity of the Cassiopeia and Cygnus sources on a frequency of 127 Mc/s with a high resolution phase sensitive interferometer were completed in the previous year. A paper on the theory of the interferometer and the method of measurement (**3**) and papers on the experimental results are in the course of publication.

A paper has been published (**4**) on the preliminary measurements at 160 Mc/s, using the transit telescope and an interferometer baseline of 20 km. Work proceeded on the construction of receivers and of larger outstation aerials for the improved interferometer to be used with the steerable telescope. A primary feed for the telescope for use at 90 Mc/s and 160 Mc/s was constructed and tested extensively. The first two outstations of the interferometer were brought into operation with cable links to the telescope set, and they were first used for observations with the telescope in December 1957. The outstation aerials (aperture 200 m^2) have proved extremely satisfactory and approach their theoretical gain.

The original interferometer was also used for two minor programmes. Observations were made of the Comet Arend-Roland as soon as this entered the

beam of the transit telescope. The observations were confused by solar emissions. No cometary emission was detected, and on some quiet days the emission was certainly less than 10^{-24}w.m.$^{-2}$cps. The same equipment was used for a detailed investigation of the polar diagram of the transit telescope, and particularly of the three 10 per cent sidelobes which have been attributed to guy wires on the original mast.

Measurements at 2800 Mc/s on the intense source in Cassiopeia have been extended in the East–West direction up to 1750 wavelengths, using the two-aerial interferometer. These measurements confirm that the diameter at this frequency does not differ from the metre wave value by more than 20 per cent and also show that the second maximum in the Fourier transform is only about 15 per cent of the zero baseline value.

Measurements have also been made on the principal sources in Cassiopeia and Cygnus, using north–south baselines up to 3400 wavelengths. These show that the north–south diameter of the Cassiopeia source is very nearly the same as the east–west diameter, indicating that the source is almost circular, as it is at metre wavelengths. By observing the Cygnus source for several hours on either side of the meridian transit it has been found that the source is markedly elongated with a minor axis of only about 20″ of arc in position angle $19 \pm 2°$.

Drift movements in the F region of the ionosphere.—The continuous monitoring on 79 Mc/s of the radio source Cassiopeia A has continued. This equipment has now yielded a record of scintillation activity which extends over four consecutive years. A critical review of all the published theories of radio star scintillations has been published (**5**), but none was found adequate to explain the finer details of the phenomenon as revealed by the above equipment (**6, 7**). A new theory has been proposed (**8**) which suggests that the turbulent motion in the upper F region which is responsible for radio star scintillations is actually set up in the dynamo region and then transferred to the F region by the close electromagnetic coupling between the two regions.

The available data on the 'ridges' discovered in 1956 have now been published (**9**). The three receiving equipments triangularly spaced by 1000 m have continued to be used to measure the velocities associated with the drift motion. These measurements, together with data from the continuously following equipment, have been sent to the appropriate I.G.Y. data-collecting centres.

The 21 cm line of interstellar neutral hydrogen.—The 21 cm studies of the interstellar medium have continued. The physical conditions within interstellar gas and dust clouds have been derived for clouds in the constellations of Auriga and Cygnus. In these regions of high dust density, the hydrogen density is a factor of 100 greater than the average for the interstellar medium; on the other hand the temperature (25–60 deg. K) is considerably lower (**10**). It is also found that the internal velocities of these and other interstellar clouds exceed thermal velocities by at least a factor of 2 and thus probably represent turbulent velocities (**11**).

A detailed study of the Cygnus-X radio source both in continuum and 21 cm line radiation shows it to be an H II region (**12**). The continuum measurements indicate that its spectrum is that of an H II region, while the 21 cm survey revealed a deficiency of hydrogen in the neutral state within the contours of

Cygnus-X. It appears that a mass of 10^7 $M_\odot$ neutral hydrogen has been converted into ionized hydrogen in this region.

Aurorae.—Radio echo studies of the aurora borealis were continued throughout 1957. Fixed and rotating aerial equipments, both on a wavelength of 4 m, were again operated continuously during the year. On a number of isolated occasions, apparatus on wavelengths of 8 m and 2 m were used to obtain auroral echoes.

The influence of the solar cycle was again marked and auroral echoes were observed during 107 hourly periods on 29 days in 1957. This compares with 57 hourly periods on 17 days in 1956 and 7 hours on 4 days in 1955. The beginning of 1957 was a period of steady activity which commenced with the great aurora of January 21–22 and reached a peak about the spring equinox. The months of April to August contained only 3 days of activity and 2 of these coincided with the commencement of the International Geophysical Year. The outstanding feature of the year's observations was the extraordinarily high activity in September. Auroral radio echoes were detected during no fewer than 50 hours on 10 days of the month and September 2–5 was the period of most sustained high activity ever recorded. The maximum activity during this period commenced at about 1400 U.T. on September 4 and continued for sixteen hours with a break in the evening hours. The strongest echoes were detected during the daylight hours of September 4. The last three months of the year showed a marked decline in the incidence of auroral echoes and there was only limited activity on 4 days during the period. An increase in activity during the equinoxes was again apparent in 1957. Auroral echoes are only observed at Jodrell Bank during geomagnetic storms (**13, 14**) and in particular the September activity correlated well with intense magnetic disturbances. Examination of magnetograms recorded at Lerwick and Eskdalemuir (Scotland) indicates that echoes are generally obtained when the current systems producing the magnetic disturbances move south of Lerwick.

Measurements of the geomagnetic field.—Continuous recordings of the horizontal (H) and vertical (V) components of the Earth's magnetic field were made throughout 1957 using fluxgate magnetometers (**15**). The sensitivities of both instruments are about 500γ per full scale deflection of the recording milliammeters. As indicated by the auroral activity described above, September was a month of extremely high magnetic disturbance. The fact that the magnetic measurements are immediately available has proved valuable in predicting the possible occurrence of auroral activity.

Meteor orbits.—The survey of sporadic meteor orbits has continued. The analysis of some 2000 meteors of magnitudes +7 and +8 is now complete (**16**), and the computation of the survey of magnitudes +4 and +5 is continuing. In the course of this, and as special investigations, a number of showers have been observed. These include the η-Aquarids, Giacobinids, December Ursids, and the Daytime Arietids, ζ-Perseids and ν-Piscids. This last shower has not been detected since 1951. Following the suggestion that meteors may arrive in small groups, an analysis of the time distribution of meteors has been made (**17**), but no evidence for anything but a random distribution in time has been found, both for shower and sporadic meteors. The continuous meteor survey equipments have operated throughout the year, and all major showers have been observed.

Meteor physics.—Work on new equipment to measure upper atmosphere pressures, densities and temperatures, using radio echoes from meteor trails, has progressed satisfactorily. In this experiment the heights of meteor trails are measured using a split beam technique (**18**), and the meteor velocity is determined by observation of the diffraction effects during formation of the trail (**19**). Theories of meteor ionization relate the atmospheric pressure at which a meteor of given mass and velocity produces its maximum ionization (**20**), and observations of height *vs* velocity thus give a measure of the pressure between altitudes of 80 and 100 km. The width of the height distribution also gives a measure of the atmosphere scale height, and so of temperature.

In earlier experiments at a wavelength of 4 m, a mean atmospheric profile was determined (**21**). With this new equipment of greater sensitivity, which operates at a wavelength of 8 m, it is hoped to investigate diurnal and seasonal variations of the properties of the upper atmosphere.

Meteor photography.—The main model meniscus Schmidt camera was completed at the University of Bristol at the end of 1956 and was installed at the selected site at Abersoch, in the Lleyn peninsula of North Wales, during the early part of 1957. The commencement of an experiment, using this camera in conjunction with radio echo equipment at both Jodrell Bank and Abersoch to investigate the relationship between ionizing and luminous efficiencies of evaporated meteor atoms, was delayed during the installation of the radio apparatus. A coded 18 blade rotating focal plane shutter was installed in the camera to enable the point on a photographed meteor trail, which corresponds with the correlated radio echo point, to be determined with much greater accuracy than has hitherto been possible. Preliminary runs with the camera show great promise. The sensitivity of the system is as predicted and two sporadic meteors are photographed per hour of exposure. Some 10 per cent of these are expected to yield correlated radio echoes. Three correlations have been obtained during the preliminary observations in 1957. One of these was a Geminid meteor of absolute magnitude $-2\frac{1}{2}$ which produced a trail over 45° long across the photographic plate. The combined programme will be continued throughout 1958.

The Pilot Model camera, sited at Jodrell Bank, was used during April and May to obtain a series of over thirty photographs of Comet Arend-Roland (1956h). The resolution of the instrument is too low to show very fine structural details but the series does show well the behaviour of the sunward ' jet ' and the overall structure and large scale changes in the tail.

During the year a satisfactory method of sensitising the spherically curved plates used in the meniscus Schmidt cameras has been evolved and perfected in collaboration with Kodak Ltd. (**22**).

E region winds.—The investigation of winds in the height region 80 to 100 km above the earth, using radio echoes from meteor trails, has continued. In this method (**23**) drifts of the ionized trails are measured by observing the change in phase of a radio echo as the path length to and from the observing station varies. Operating at a radio wavelength of 8 m, a change in phase of 45° or 1 m in path length is measurable, and winds of the order 1 to 100 m sec^{-1} can be determined using meteor echoes with durations of 0·1 to 1 sec.

Measurements of the winds in this region form part of the Jodrell Bank International Geophysical Year programme, and observations are carried out on

the World Days. Because of the large amount of observational material which accumulates, measurements are not necessarily made during all the Special World Intervals. As we are primarily interested in studying ionospheric movements during periods of high magnetic activity, measurements are made only in those Special World Intervals which are very disturbed magnetically. As this condition is visually indicated by the observation of radio echoes from the aurora, the presence of such echoes is taken as the selection criterion. Daily observations of the wind hourly intervals are then analysed for prevailing and periodic components (**24**), of which the 12-hour component is the largest. Results obtained during 1957 are in good agreement with those obtained during previous years (**25**).

Lunar echoes.—The analysis of the previous year's observations of the long period fading of moon echoes on two close spaced frequencies has been completed. This fading is caused by the Faraday effect in the Earth's ionosphere and provides a means of measuring the total electron content of the ionosphere. The results obtained so far lead to the conclusion that there are approximately three times as many electrons above the level of the critical frequency of the F_2 region as below. By assuming a linear decrease of ionization above the height of maximum electron density, it may be shown that the ionosphere extends to 600 to 700 km (**26**).

A detailed examination of the rapid fading of moon echoes has been carried out. This fading is caused by the Moon's libration, which introduces phase changes between the signals returned from different scattering centres on the Moon's surface. By measuring the correlation between adjacent echoes as their time separation is varied, it has been possible to measure the echo power spectrum. This is considerably narrower than would be expected from a Moon which behaves as a uniformly bright reflector, and indicates that the echo is returned from a region at the centre of the visible disk, which has a radius of about one-third of the lunar radius. This conclusion is supported by (*a*) pulse shape observations which show that the echo is not lengthened by more than 1 m sec, (*b*) range measurements which show that to within the experimental error ($\pm$ 1 m sec) the range of the echo and the front edge of the moon are the same, and (*c*) the signal to noise measurements which show that the signal intensity does not fall when the pulse length is reduced from 10 to 2 m sec. A scattering law for the lunar surface has been deduced and indicates that the scattering is almost 'specular'. This work shows that the Moon could be used in an Earth–Moon communication circuit where modulation frequencies of at least 1 kc are possible (**27**).

Optical interferometer.—A series of papers on the interferometry of the intensity fluctuations in light has been prepared. The first paper (**28**) gives an account of the general theory for plane waves; and the second paper (**29**) discusses the practical case of partially coherent light and gives a detailed account of a laboratory experiment which was designed to test the theory. The third and fourth papers deal with the application of the technique to astronomy and have not yet been published. To complete the laboratory checks of the principles involved, an experiment has been carried out in cooperation with the Division of Radiophysics in Sydney, Australia, in which the correlation between the times of arrival of individual photons was detected by coincidence counters (**30**).

The design of a stellar interferometer which is intended to measure the angular diameters of stars brighter than apparent photographic magnitude +2·5 is at present under consideration.

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University Observatory, Oxford

(*Director, Professor H. H. Plaskett, F.R.S.*)

Observations.—The spectroscope of the 35·2 m telescope was brought into use for the first time in the 1957 observing season. With it Dr Adam obtained a series of spectra for a new determination of the limb effect. Subsequently with the Babcock grating and a Babinet compensator Dr Treanor measured the elliptical polarization of the Zeeman components of Fe I, λ 6173·35 for a number of sunspots. Mr Nichols used the 19·8 m telescope through nearly the whole of the season for interferometric measurement of the red shifts of the H and K lines.

Solar chromosphere.—From interferometric spectra obtained by Dr Treanor, Mr Clube (3) has measured the profiles of Hα and D_3. From the Doppler half-widths, after correction for self absorption in Hα, he finds a turbulent velocity in the chromosphere of 17 ± 2 km sec^{-1} and a kinetic temperature of $20\,000° \pm 15\,000°$. The inaccuracy in the determination of the kinetic temperature, which arises from observational errors in the line profiles, is greatly magnified because

of the dominant contribution of turbulence to the Doppler half-widths. Among other chromospheric investigations in progress, Dr Hart is measuring the profiles of the H and K lines from spectra obtained with the 19·8 m telescope in 1956.

Red shifts.—Dr Adam and Mr Nichols (1) have investigated the accuracy of solar and laboratory wavelengths as found interferometrically by the method of circular channels. They find such wavelengths to be free from scale error and accurate to a milliangstrom. The red shifts so determined at Oxford, as well as those found by Burns at Allegheny, have been used by Dr Adam (2) to examine the radial-current hypothesis as revived and revised by Schröter. While more observational material is required, the existing evidence lends little support to Schröter's hypothesis. In this connection a substantial addition to the number of red shifts measured at Oxford has been made by Mr Nichols and Mr Clube, and their results will shortly be communicated to the Society.

From his interferometric observations in 1957 Mr Nichols has obtained surprising results for the Ca II H and K lines. The red shift for K is 18·5 mA and for H 9·2 mA, while the predicted relativity shift is 8·4 mA. Mr Nichols plans to make a further series of observations of these lines in the 1958 season.

Pressure shifts.—Any interpretation of solar red-shifts must take into account the contribution of pressure shifts. These are now under experimental investigation by Dr Hindmarsh for Ca I, λ 4227, in absorption using the Babcock grating, and by Mr Thomas for emission lines of argon using interferometric methods. The results so far obtained show substantial departures from Lindholm's simple classical theory of the line shifts which accompany collisional broadening.

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University Observatory, St. Andrews
(*Director, Professor E. Finlay-Freundlich*)

Scientific research

(*a*) *Workshop report* (Mr Waland). The aspherising of the 37-inch Schmidt plate is in progress. A permanently incorporated axial shift mechanism for the Schmidt plate has been designed and is at present under construction. Work on the fine parts of the inner defining tube flotation system is completed.

(*b*) *Auroral Station* (Dr Jarrett). Mr J. W. Campbell joined the staff as a research student. He is taking part in the International Geophysical Year auroral research programme.

The all-sky camera for recording aurorae received from the Uppsala Ionospheric Observatory has been mounted and tested. It is now in regular operation every night.

The *f*/0·7 auroral spectrograph has undergone considerable readjustment and is now considered fully operational. Spectra have been obtained on some twelve occasions during the past year. The spectrograph is also in use on the night sky.

Preliminary tests are in progress with the radio echo equipment.

All the above projects are part of the International Geophysical Year programme.

(*c*) Dr J. Cisar continued with his programme of distribution of cluster variables and survey of emission nebulae.

(*d*) A D.S.I.R. grant for special research made it possible for Mr E. G. Forbes to begin with an extensive programme of observations of the red shift of the solar lines with the solar telescope at the Osservatorio Astrofisico di Arcetri (Florence) which Professor Righini kindly placed at the disposal of Professor Finlay-Freundlich.

(*e*) Professor Finlay-Freundlich completed the edition of his textbook on " Celestial Mechanics " which will be published by the Pergamon Press, London.

(*f*) During the visibility of the two Comets in 1957 Mr T. Slebarski and Dr J. Cisar took a number of photographs of the Comets showing progressive changes in the structure of nucleus and tail.

Norman Lockyer Observatory of the University of Exeter

(*Superintendent, Mr D. R. Barber*)

Observational work connected with the current programmes (enumerated in the 1956 report) has been continued whenever weather conditions have allowed. In addition, photographic, and spectrographic observations of Comets Arend-Roland, and Mrkos were made during the year.

Colour temperature.—Additional spectra of " secondary standard " stars were secured with the 12-inch McClean prismatic camera during 1957, but the observational material is still incomplete. Six spectrograms of γ Cassiopeiae, including three taken in the far red and infra-red regions, were obtained with the same instrument.

Twilight airglow.—Routine observations of the sodium emission-absorption pattern in the twilight sky, made with the twin-lens-mirror camera, continued throughout the year, and 15 satisfactory photograms were secured. Some focus plates were taken with the large Littrow spectrograph.

Comets 1956h and 1957d.—Eight photographs of Comet 1956h (Arend-Roland) were obtained with the Mond Astrograph in April, and two of Comet 1957d (Mrkos) under difficult observing conditions in August. Spectrograms of each comet in the photographic region were also secured with the McClean telescope.

Publications.—The following *Reprints* have been issued during 1957: *Series A*, Nos. 14 and 15; *Series B*, Nos. 14, 15, and 16.

Visitors.—The Observatory was opened to the public on 1957 July 18, when 351 persons attended. The total number of visitors for the year was 572.

Dunsink Observatory

(*Acting Director, Dr M. J. Smyth*)

Staff.—The Director, Professor H. A. Brück, resigned in September to take up an appointment as Astronomer Royal for Scotland and Director of the Royal

Observatory, Edinburgh. During the ten years of his directorship since the Observatory was re-opened in 1947, the instrumentation has been entirely reconstructed and modernised under his enthusiastic guidance; he has led two eclipse expeditions; the ADH-Telescope has been erected and Dunsink has joined in the six-nation plan for operating the Boyden Observatory; and the Observatory has acted as host to the International Astronomical Union and to the Royal Astronomical Society.

Dr M. T. Brück resigned her post as Research Associate in November. Miss S. M. P. McKenna, a graduate of University College, Dublin, joined the Observatory in August as Scholar. The post of Junior Assistant remains unfilled.

Solar work.—Spectrograms down to 3060 A have been obtained to complete the programme of photometry of the ultra-violet solar spectrum. Dr M. T. Brück has completed the direct-intensity photometric registration of the plates and the tracings have been forwarded to Utrecht Observatory.

Spectrohelioscope observations of solar activity have been continued by Dr M. T. Brück and Miss McKenna, and results forwarded to I.G.Y. Data Centres. A 35-mm camera has been fitted for experiments in sequence photography of the Hα line during flares. A recorder for sudden enhancements of atmospherics (S.E.A's.) has operated satisfactorily throughout the year.

A pair of matched EMI photomultipliers has been installed on the concave grating spectrograph, and attempts will be made during the coming year to detect displaced H- and K- line absorption due to corpuscular emission associated with flares.

Stellar work.—A temporary D.C. amplifier and chart recorder have been attached to the 28-inch reflector. A programme on the short-period variable ν Eridani was spoilt by bad weather.

Dr Smyth obtained photoelectric measurements of the nucleus of Comet Arend-Roland on a number of nights, using a varying diaphragm proportional to one minute of arc at unit geocentric distance. This method promises to give a consistent measure, but has not been widely adopted. Publication is delayed pending remeasurement of some of the comparison stars; preliminary reductions do not support a correlation of observed variations with sunspot numbers.

Dr Smyth has made laboratory tests of an E.M.I. 13-stage quartz-window photomultiplier for use with the 60″ Boyden reflector.

ADH-Telescope and Boyden Observatory.—Dr Smyth attended a meeting in Brussels of the Administrative Council of the Boyden Observatory. Lack of staff has again made it impossible to send an observer from Dunsink to South Africa or to make progress with the measurement of the existing cluster plates.

Miscellaneous.—A laboratory has been constructed for cleaning and aluminising telescope mirrors and the 22-inch tank has been installed.

A number of photographs of the Soviet artificial Earth satellites have been obtained, using the Shortt clock seconds impulses to impress timing marks on the trails, and measurements have been circulated to interested observatories.

Visitors.—Members of the Dublin Centre of the Irish Astronomical Society, and about 120 members of the British Association for the Advancement of Science, visited the Observatory. Visiting astronomers included Professor F. J. M. Stratton, Professor W. H. McCrea, and Dr A. R. Hogg.

Dominion Observatory, Ottawa

(*Director, Dr C. S. Beals, F.R.S.*)

Positional astronomy.—The time service of Canada has been maintained as usual based on P.Z.T. observations corrected for polar wandering and annual fluctuation. Information on the frequencies of quartz oscillators at the Observatory and the National Research Council were exchanged daily. Continuous time signals with a voice announcement each minute were broadcast via CHU on 3330, 7335 and 14670 kc/s.

A dual rate Moon-camera has been adapted to the 15-inch equatorial, and the broken-type Cooke Transit has been restored to service for I.G.Y. projects.

The meridian circle has been used on two major observing programmes, 8750 observations having been made. The new building for the mirror transit instrument has been completed and mounting of components on the piers has commenced.

Stellar Physics Division.—The Super-Schmidt meteor cameras at Meanook and Newbrook, Alberta, secured simultaneous photographs of fifteen meteors suitable for detailed height, velocity and deceleration measures. Seventeen meteor spectrographs are now in routine operation at these stations and during the year they produced fifteen spectra.

The Observatory is participating in the I.G.Y. programme of continuous observation of the Sun, using a birefringent filter and automatic camera.

Plans were laid for the establishment of a radio observatory to engage in 21 cm galactic research. A quiet site in Southern British Columbia was selected and the order for an equatorially mounted 84 ft parabolic antenna has been placed.

Seismological Division.—The Seismological Division has continued to operate the permanent network of the Canadian stations; during the year the station at Resolute was rebuilt and equipped with new instruments, and the station at Kirkland Lake was closed permanently. The bridge, developed for the calibration of electromagnetic seismographs, has been perfected, and has been used to calibrate the seismographs of Eastern and Western Canada. Studies on the mechanics of faulting have continued; solutions have been published for 38 additional earthquakes, and a review has been made of the implications of plasticity theory to the mechanics of faulting.

Geomagnetism Division.—Magnetic Observatories were maintained at Agincourt, Ontario; Meanook, Alberta; Baker Lake and Resolute Bay, N.W.T. I.G.Y. observatories at Victoria, B.C., and Yellowknife, N.W.T., were in operation in June. Earth current recordings continued at Meanook. Magnetic survey operations were carried out in Eastern Canada by ground parties and the Dominion Observatory three-component airborne magnetometer. A nuclear precision magnetometer was constructed and put into operation at Ottawa. The construction of detailed isogonic charts for the Provinces continued and those for Manitoba, Saskatchewan, and Alberta were issued. The astatic magnetometer was used in the analysis of rock cores from suspected meteor craters. Six papers were published dealing with various aspects of geomagnetism.

Gravity Division.—Two laboratory projects involving the development of gravity measuring instruments are nearing completion. An improved bipendulum apparatus has been constructed and rigorous field tests satisfactorily

carried out. Progress in the development of a vibration gravimeter for measuring gravity at sea advanced to the point where tests of its performance were possible. Through the co-operation of the Netherlands Geodetic Commission, comparisons were made against Vening Meinesz pendulums in a submarine during December.

Another laboratory project involved the conversion of gravimeters to continuous recording instruments for Earth tide studies during the I.G.Y. These instruments have been placed in operation in Ottawa and Resolute Bay, N.W.T.

Regional gravity mapping of Canada was continued with extensive surveys in the Gaspe region, Manitoulin Island and North Shore region of Lake Huron, and throughout the Prairie Provinces.

Gravity measurements were used for the first time in Canada for application to problems of geodesy. Using high speed computing techniques, an analysis of gravity data for a large area in Western Canada was completed to provide relative values for geoidal heights and deflections of the vertical.

David Dunlap Observatory, University of Toronto

(*Director, Professor J. F. Heard*)

Radial velocities.—Measurements have been completed for 200 stars in extensions of certain of the Kapteyn areas. Some progress has been made in observations of faint OB stars, but other kinds of observations have recently claimed a greater proportion of telescope time at the expense of velocity observations.

Heard has obtained a velocity curve for both components of the eclipsing binary SZ Psc, and Bakos has observed a primary minimum at J.D. 2436114·567. Both spectrographic and photometric observations indicate that the period of 3·96637 days given by Rugener needs to be revised. Heard has obtained velocity curves and Bakos has obtained light curves from extensive observations of the short-period variable, 12 Lac, made during September of 1956.

Miss Northcott has prepared for publication orbits of the double-line spectrographic binaries, HD 15138, 82780, 196133 and 200391.

Photometry.—Mrs Hogg has continued observations with the 19-inch telescope for the determination of periods of bright slow variables in clusters and also with the 74-inch telescope for the study of variables in some of the fainter and more difficult clusters.

Bakos has completed a study of the apparent and absolute magnitudes of the components of 110 visual binaries.

Oke has used the photoelectric spectrophotometer to obtain monochromatic light curves and relative energy distributions between $\lambda 3400$ and $\lambda 5200$ for the cepheid variables η Aql and δ Cep. The observed energy distributions are being compared with those from model stellar atmospheres to obtain temperatures, pressures and radii as functions of phase.

Searle and Oke are using the photoelectric spectrophotometer to set up a sequence of 24 standard stars distributed over the northern sky. The energy distribution of each star is to be compared with that of Vega.

Stellar Luminosities.—MacRae has investigated the use of the photoelectric spectrophotometer for the measurement of equivalent widths in the spectra of B- and A-type stars. Internal agreement of individual tracings is within a few per cent, and there is good agreement with the best values determined photographically elsewhere. A programme involving stars in clusters and associations is being developed.

Computation.—Oke and Demarque have computed a series of homogeneous models for massive stars.

Searle has completed an investigation of the hydrogen recombination spectrum, the analysis taking into account the first ten principal quantum levels and their angular momentum sub-levels. The recombination coefficients for the higher levels have been computed.

Radio-astronomy.—A large welded-aluminium horn has been installed at the Observatory as a transit antenna. Two parabolic cylinder antennas have been constructed. These, along with the horn, will act as a triple interferometer for the absolute measurement of the flux from discrete radio sources. A routine solar patrol, with the equatorial zig-zag array and the horn, was begun late in the year as part of the I.G.Y. programme. This project, operating at 320 Mc/sec, is being directed by MacRae in collaboration with the Department of Electrical Engineering of the University of Toronto.

Bibliography.—Mrs Hogg has continued her bibliographical work on both galactic and globular clusters, with the expectation of soon preparing a supplement to the Bibliography of Individual Globular Clusters (D.D.O. Pub. 20, 1947).

Earth satellites.—Radio, visual and photographic observations of satellites 1957α and 1957β were made. Antenna arrays were constructed for observations on both the 40 and 108 Mc frequencies. The Observatory has undertaken to communicate observations to the Soviet I.G.Y. committee and to the U.S. Air Force Cambridge Research Centre as requested.

Staff.—Dr Helen S. Hogg has been promoted to the rank of Professor, and Dr Leonard T. Searle to the rank of Assistant Professor.

Publications.—Since the last report, Communications D.D.O. Nos. 38, 39, 40, 41 have been issued.

Report of the Dominion Astrophysical Observatory

(*Dr R. M. Petrie, Dominion Astrophysicist*)

Staff.—Miss J. K. McDonald rejoined the staff in July after spending an academic year with the Astronomical Department of the University of California as a guest lecturer. Mr E. K. Lee went on leave of absence in September to undertake graduate studies in astronomy at the University of Michigan. Mr P. E. Argyle was absent from the Observatory for some months assisting officials of the Dominion Observatory in a survey to choose a suitable site for a radio telescope. Mr W. G. Milne, of the seismological section, returned to the Observatory in February after spending a year and a half at the University of California in geophysical studies. National Research Council Post-doctorate Fellow Dr R. Wilson, of the Royal Observatory, Edinburgh, took up residence at the Observatory in April and Dr R. S. Kushwaha, a similar Fellow, entered

on the second year of his Fellowship in September. Mr B. Caner joined the staff in July to operate and maintain several installations under the International Geophysical Year programme.

The following held temporary appointments during the year : Dr Paul W. Merrill, Mount Wilson and Palomar Observatories ; Dr E. G. Ebbighausen, University of Oregon ; Mr E. Butkov, McGill University ; Mr J. L. Climenhaga, University of British Columbia ; A. K. Goodacre, University of British Columbia ; S. C. Morris, University of British Columbia.

Miss McDonald attended a Canadian Conference of Physicists and Mathematicians at Banff, Alberta, in September and presented an invited paper on "A Problem in Astrophysical Programming for Ferut ".

Miss A. B. Underhill spent some time at the computational facility of the Bureau of Standards at Boulder, Colorado, to programme and compute absorption coefficients on the various hydrogen series in absorption for application to broadening functions and Stark effect studies in the analysis of solar and stellar spectra.

A. McKellar was elected President of the Astronomical Society of the Pacific for a second term and R. M. Petrie completed terms as President of the Royal Astronomical Society of Canada and as Vice-President of the American Astronomical Society.

Spectroscopy.—Work has continued on the programme of detailed studies of ζ Aurigae type stars. Observations with high dispersion have been concentrated upon ϵ Aurigae and VV Cephei. VV Cephei underwent eclipse during 1957. The first contact, according to the spectroscopic information, occurred on June 29 and second contact on July 29. A good series of spectrograms was obtained between first and second contacts and a number of spectrograms for comparison purposes was obtained during totality. Third contact was predicted for the middle of October and a number of spectra was obtained but it was not until mid-December that spectroscopic evidence of the emergence of the early-type star was obtained. Observations of ϵ Aurigae have been made in the visual and photographic regions. The eclipse ended in June but chromospheric absorption was still visible at the end of the year.

A. McKellar and R. M. Petrie have completed a paper on material obtained during the 1951 eclipse of 31 Cygni. This gives a survey of the observational material, the radial velocities of chromospheric lines, and an estimate of the probable dimensions and absolute magnitude. They arrive at the following dimensions for the system of 31 Cygni :

	Primary star	Secondary star
Spectral type	K3Ib	B3V
Absolute magnitude (M_v)	−4·0	−2·0
Mass (Mass ratio 2·0 : 1)	18$\odot$	9$\odot$
Radius	174$\odot$	4·7$\odot$

K. O. Wright has made a detailed study of the ordinary and chromospheric spectra of 31 Cygni during the partial and chromospheric eclipses and during totality. He finds that the light ratio of the components of 31 Cygni is 0·9 at λ3900. The corresponding numbers are 1·2 for 32 Cygni and 2·0 for ζ Aurigae. The spectrum of the secondary star of 31 Cygni is about B3 ; the absolute magnitude about −2·0 ; and the mass ratio about 2·0. A curve of growth

study has been made for a large number of chromospheric lines within three weeks of totality. From the curve of growth analysis the temperature is found to vary from 2800° at one day outside total eclipse to 5000° at 12 days outside of eclipse and the spectrum of the chromospheric absorption shows a corresponding variation from about spectral type K to spectral type F. The density gradient in the atmosphere of the late-type star shows a sharp increase about 5 days before totality if one considers the lines from the neutral atoms but the gradient is nearly constant for the ionized atoms.

The profile of Hα in the spectrum of ε Aurigae during the years 1955 to 1957 has been investigated by K. O. Wright and R. S. Kushwaha. Marked changes in the profile are observed especially near the time of mid-eclipse. The emission feature at Hα is found to be variable and it is concluded that Struve's suggestion of an envelope around each star with an exchange of gas between the two stars fits the observations better than any other model which has so far been proposed. K. O. Wright and E. Butkov have made a survey of the radial velocities and line intensities of the chromospheric lines in the spectrum of ε Aurigae before, during, and after eclipse. The chromospheric lines appear to be composed of at least two components and this duplicity seems to persist for at least 3 months near the end of totality. Chromospheric velocities are positive relative to the velocity of the star before eclipse and become negative after eclipse, and the amount of the displacement relative to the star appears to decrease in the outer layers. The absorption lines of the normal spectrum appear to change in shape, thus complicating the analysis of the spectrum. Chromospheric lines of neutral iron are observed at least two months after the eclipse.

High dispersion spectra of VV Cephei obtained during ingress and totality in 1956 and 1957 are being studied by A. McKellar and K. O. Wright. Double chromospheric lines are observed before first contact and these appear to arise in some kind of a double cloud phenomenon, although there is evidence for emission lines between the absorption components of the ultraviolet lines of ionized titanium. There is some evidence for the existence of circumstellar absorption of neutral and ionized calcium and neutral chromium. Measurements of the emission at Hζ indicate that the emitting shell of the B star is not obscured until at least two weeks after totality.

Miss A. B. Underhill has continued her work on the analysis of O-type spectra. Spectra of 9 Sagittae have been subjected to a detailed analysis between wave-lengths 3100 and 6700 A. About 1000 spectral lines have been measured and largely identified in this region, if one includes a considerable number of lines of marginal visibility. Eighteen atoms or ions are considered to be represented with certainty, 9 are probably represented, and 7 are possibly present. Miss Underhill has investigated the line 5696 C III which appears in emission in spectra of Of stars and the late O supergiants. An exciting mechanism is proposed in the ionization of singly ionized carbon from 3^2D level to the 3^1D level of doubly ionized carbon by the absorption of λ303 radiation of ionized helium. The 3^1D level of doubly ionized carbon is the upper level for 5696 emission as the atom cascades to its position of lowest energy. An excess of λ303 energy is expected from the appearance of other features in the spectra of the high temperature stars.

G. J. Odgers spent some time as a guest investigator at the Mount Wilson Observatory during the summer and was able to obtain numerous high dispersion

spectra of a number of β Cephei stars in the photographic region and at Hα where variable emission is present. Intensive coverage was obtained at the double line phases of the stars 12 Lacertae and HD199140.

Miss Underhill has made estimates of the energy distribution at wave-lengths shorter than 900 A from stars in the temperature range 50 000° to 80 000°. Departures from black-body radiation in the short wave-length regions may explain the separation of Wolf Rayet stars into C and N sequences. In order to clarify the matter, observations have been started to investigate the completeness of the exclusion of nitrogen lines from the carbon sequence and vice versa.

K. O. Wright has obtained high dispersion spectra of the shell star 17 Leporis between 1957 January and March. Large changes are observed in the appearance of the shell lines which are displaced negatively with respect to the stellar line at 4481. One shell component is usually present at a relative velocity of −80 km/sec and a sharper component is seen sometimes between that velocity and the velocity of the star. The spectrum of the star appears to be of type B9, while that of the shell is about A2.

R. Wilson has made spectroscopic observations, using polarizing equipment, in an attempt to detect a galactic magnetic field. Spectra of stars in Cygnus and Cepheus are compared with spectra of stars at high galactic latitudes. No effect has been detected with single-prism spectrograms. Observations have been made also of the diffuse interstellar lines at λ4430 and of those diffuse lines in the yellow and orange regions of the spectrum. The two polarized components of 4430 are equal and similar observations are made for the other diffuse interstellar lines which have been measured. The components of 4430 are found to be bell-shaped and the line extends over a distance of about 150 A. An analysis of published material on the diffuse interstellar lines in the visual region shows that in regions of strong polarization the lines 5780 and 6284 are stronger per unit colour excess than in regions of small polarization. A simple treatment indicates that the projected length of the interstellar " needles " is smaller when polarization per unit excess is large, in agreement with the theory of Davis and Greenstein that the needles spin about their short axes due to paramagnetic relaxation. This would mean that the magnetic field lies in the plane of the galaxy.

A. McKellar and J. L. Climenhaga have studied spectrograms of Comets 1956h (Arend-Roland) and 1957d (Mrkos). The observed and calculated profiles of the λ3883 CN bands are in satisfactory agreement. A spectrogram of Comet 1957d in the visual region showed a rich emission spectrum dominated by very strong Na D lines. Over fifty emission features were measured between λ5000 and λ6700 and many of these emissions are identified with emissions in the oxy-ammonia flame, strengthening the previous identification with the NH_2 bands.

Theoretical studies.—G. J. Odgers has further developed and applied the idea of a dissipating shock wave to accurate radial velocity material in β Cephei stars. A general agreement is obtained with the observed radial velocity curves. The analysis has been extended to the problem of the long period variables in collaboration with R. S. Kushwaha. It was found that the shock will be dissipated in about 100 days in the extensive atmospheres of the long period variables, in fair accordance with the observations.

The question of stellar origin has led to the consideration of turbulent motions in a self-gravitating mass of gas. Some solutions of the equations describing

these processes have been obtained by G. J. Odgers in collaboration with R. W. Stewart. The results suggest that gravitational instability works together with turbulence to produce stellar type condensations in the gas cloud. G. J. Odgers has studied the application of recent theories of electron broadening in the helium atom to stellar spectra. It is found that the assumption of the so-called Foster-Douglas cycle is unnecessary to explain the helium lines as observed in the spectra of B-type stars.

R. S. Kushwaha has been studying problems of thermal convection in radiative polytropic atmospheres. The depth of the disturbed zone for the fundamental node is found to be much larger than in the case where radiation is neglected. This work is being continued.

Miss Underhill has spent some time working at the Bureau of Standards computing facility at Boulder, Colorado, on the Stark effect in hydrogen in stellar atmospheres. The *f*-values of the Stark components have been computed up to $n = 18$ for the Lyman, Balmer, Paschen and Brackett series. A programme for the computation of the Verweij function $S(\alpha)$ has been set up and coded.

Stellar motions.—Observations have been continued with single-prism spectrographs to complete the principal current radial velocity programme of faint B stars and stars near the North Galactic Pole. About one thousand spectrograms have been measured for radial velocity during the year, mostly by D. H. Andrews, E. G. Ebbighausen, A. B. Underhill and R. M. Petrie. The spectra so measured have been largely those of faint B stars, of members of associations and of spectroscopic and visual binaries.

A study of the motions of a group of B stars known as the Cassiopeia-Taurus group has been completed by R. M. Petrie. New radial velocities and spectroscopic absolute magnitudes have been determined and used in conjunction with recent improved proper motions. Convergence, space motions, and distances have been derived on different assumptions as to the origin and kinematical nature of the group. It is concluded that the stars are a sample of the general population without sharing common motion.

Wave-length standards for radial velocity measures with low dispersion applicable to spectral types Ao to K8 have been obtained by R. M. Petrie, D. H. Andrews, and J. K. McDonald.

Binary stars.—Spectroscopic observations of about one dozen visual binaries have been continued during the year, largely by Miss A. B. Underhill. J. A. Pearce has computed orbital elements and completed spectroscopic studies of the stars HD 23642, κ Cancri, HD 190786, and λ Andromedae. E. G. Ebbighausen and R. M. Petrie have investigated the spectroscopic binaries θ^2 Tauri, ν Orionis, and ω Ursae Majoris comparing high dispersion radial velocities obtained at Victoria with material obtained several decades earlier, mostly at other observatories. The comparison suggests further observations in order to strengthen the evidence which points towards changes in orbital elements, especially in the system ω Ursae Majoris. R. M. Petrie has commenced two-prism observations of about fifteen spectroscopic binaries of early-type and short period where intervals of twenty years or more exist between the first and second orbits. The purpose is to lay a foundation for a precise study of orbital changes. In the course of this work the star HR 8800 has been discovered to exhibit a relatively rapid change in ω. The first observations in 1919 gave a value $\omega = 127°$, while the 1957 series will define a value in the neighbourhood

of 200°. This is perhaps the clearest case of apsidal motion in spectroscopic binaries.

Seismology.—The five stations of the western network operated satisfactorily during the year and a new station was installed at Lillooet, B. C., on August 1. An active year was ushered in with a series of major earthquakes in the Aleutian Island chain in March and April. Three minor earthquakes were felt locally and several others were felt in the Puget Sound area. The last half of the year has been occupied in planning extensive coverage of a large explosion to demolish Ripple Rock in Seymour Narrows timed for 1958 April. A number of stations, additional to the network are planned along the C.P.R. right-of-way from the West Coast eastward into Alberta and instruments will be set up close to the explosion area.

Measures of local crustal speeds of seismic waves continue with the assistance of the R.C.N. and Pacific Naval Laboratories. A series of depth charges has been exploded in the Gulf of Georgia and off Vancouver Island. A larger fixed explosive was detonated in one of the Mainland inlets. Included in this programme were several land blasts set off in commercial mining operations. A good value of wave velocity should result from these explosions.

International Geophysical Year.—Several installations have been operated by B. Caner for the Dominion Observatory, the National Research Council and the Defence Research Board as follows :

(1) A magnetic observatory which has been in operation since July 1.

(2) An auroral all-sky camera and an auroral intensity recorder operated since July 30.

(3) An ionospheric sounder in operation since May 23.

Instrumentation.—Plans were completed for a proposed 48-inch reflecting telescope and the enclosing dome and coudé spectrograph. The telescope has been ordered and specifications have been written for the dome and coudé room. The telescope will have a primary mirror working at $f4$ and, in combination with hyperbolic secondaries, will give foci at $f18$ and $f30$. It is planned to use the new telescope to feed a powerful coudé spectrograph, to serve as a photo-electric telescope and to be available for experimental purposes.

An electronic guider for use at the Cassegrainian focus of the 73-inch telescope has been built and assembled on the telescope, and is undergoing trials and adjustments. The device will do away entirely with manual guiding and will free the observer from constant attendance at the eyepiece. This instrument has been designed and built at the Observatory by P. E. Argyle and A. R. Salonen.

During the year the electrical controls of the telescope and dome were completely renewed and modernized. The quick motion speeds on the telescope were made variable and the controls were transferred to a movable console. Numerous other improvements were introduced into the electrical system.

A new measuring machine with a screw of 1 mm pitch and a travel of 25 cm has been acquired and is being fitted with necessary parts to convert it to a projection machine.

D. H. Andrews has constructed a mechanical device which will give very quickly precessional corrections in right ascension and declination to apply to coordinates for any year between 1900 and 2000.

A building to house the machine and carpentry shops has been planned for some time. Construction commenced in October and it is expected that the new premises will be occupied early in the new year.

The shop staff carried out all necessary maintenance and made many improvements to the telescope and auxiliary equipment during the year.

Publications.—The following papers were submitted for publication :

Publications

Vol. X, No. 19. " Four B-type Model Atmospheres " by A. B. Underhill.
Vol. X, No. 20. " Homologous Solutions of Equations of Stellar Structure " by G. J. Odgers.
Vol. X, No. 21. " Redetermination of the Spectrographic Orbit of δ' Lyrae " by E. H. Richardson and A. McKellar.
Vol. X, No. 22. " Wave-length Standards for Radial Velocity Determinations Spectral Types A3–K8 with Low Dispersion " by R. M. Petrie, D. H. Andrews, and J. K. McDonald.
Vol. X, No. 23. " Relative Spectral Gradients as Measured in High-Dispersion Grating Spectra " by Bengt Westerlund.
Vol. X, No. 24. " HD 23642, A Spectrographic Binary in the Pleiades " by J. A. Pearce.
Vol. X, No. 25. " The eclipsing Variable HD 190786 (V477 Cygni) " by J. A. Pearce.
Vol. XI, No. 1. " Victoria Observations of 31 Cygni " by A. McKellar and R. M. Petrie.

Contributions

No. 53. " Proceedings of the National Science Foundation Conference on Binary Stars ".
No. 54. " Double Lines in the Spectrum of ρ Cassiopeiae " by W. P. Bidelman and A. McKellar.
No. 55. " On the Origin of the λ5696 Emission in O Stars " by A. B. Underhill.
No. 56. " Introductory Remarks Concerning the Emission Lines in Of and W Stars " by A. B. Underhill.
No. 57. " Observations of Hα in the Spectrum of ϵ Aurigae obtained during and outside of Eclipse " by K. O. Wright and R. S. Kushwaha.
No. 58. " Spectrographic Observations of VV Cephei during Ingress and Totality, 1956–57 " by A. McKellar, K. O. Wright and J. D. Francis.
No. 59. " Recent Changes in the Spectrum of 17 Leporis " by K. O. Wright.
No. 60. " The Orbit of the Spectroscopic Binary Delta Capricorni " by Mary Jane Stewart.
No. 61. " New Radial Velocities, Space Motions and Absolute Magnitudes of Stars of the Cassiopeia-Taurus Group " by R. M. Petrie.

The following chapters have been prepared for G. P. Kuiper's Compendium of Astronomy and Astrophysics, " Stars and Stellar Systems " :

Vol. II, Chapter 19. " Radial Velocity Determinations " by R. M. Petrie.
Vol. II, Chapter 21. " The Determination of Orbital Elements of Spectroscopic Binaries " by R. M. Petrie.
Vol. VI, Chapter 17. " Early-type Stars with Extended Envelopes " by A. B. Underhill.

Union Observatory, Johannesburg

(*Director, Dr W. S. Finsen, Union Astronomer*)

Staff.—Dr W. H. van den Bos retired on superannuation on 1956 December 31. Miss E. M. Bernardy was appointed Library Assistant on 1957 July 1. At the end of the year the staff was as follows : W. S. Finsen, J. Hers, J. A. Bruwer, P. C. Seligmann, J. Churms, N. van Delen (Mechanician), Miss D. M. Howe, Miss E. M. Bernardy. Two professional posts were vacant.

As in previous years, a close liaison was maintained with the Transvaal Centre of the Astronomical Society of Southern Africa and it is a pleasure to acknowledge once again the valuable help rendered to the Observatory by the following Members : Messrs H. C. Lagerweij, J. H. Botham, I. R. H. Brickett, G. F. G. Knipe, M. D. Overbeek, C. N. Williams, K. G. Fuhr, A. Johnston and C. Pikoos.

Dr A. M. J. Gehrels of the Department of Astronomy, University of Indiana, worked at the Observatory as a guest astronomer from the middle of April to the end of June on an investigation of Trojan minor planets. During his stay he worked also at the Radcliffe and Boyden Observatories.

Leiden Southern Station.—During the year the Rockefeller Telescope of the Leiden Southern Station was transferred from the Union Observatory grounds in Johannesburg to the Hartbeespoort Annexe, where it occupies a site in close proximity to the Franklin Adams Telescope and the Leiden Observatory's " Light Collector ". The new Southern Station was formally opened on September 9 by the Hon. J. H. Viljoen, Minister of Education, Arts and Science at a ceremony graced by the presence of Dr J. E. Baron de Vos van Steenwijk, President Curator of the University of Leiden and Chairman of the Leiden Observatory Foundation.

Instrumentation.—A photo-electric photometer, embodying an E.M.I. photo-multiplier tube, was built for use with the Franklin Adams 6 and 7-inch Twin Telescope. With the assistance of Dr A. Muller, Bruwer completed his photo-electric photometer for use with the Franklin Adams Telescope at Hartbeespoort. Knipe adapted his photo-electric photometer for use with the 9-inch telescope.

Two cameras were constructed with lenses of 20-inch focal length and aperture $f/5{\cdot}6$ using 20×20 cm plates. One has been mounted on the 9-inch telescope.

A Markowitz dual rate Moon Camera was received on loan from the U.S. Naval Observatory and has been adapted for the Franklin Adams Twin Telescope by means of a specially constructed breechpiece.

A heavy-duty lathe and a surface grinder were acquired for the workshop.

Astronomical research.—With the 26½-inch refractor, Churms made 191 micrometer measures of double stars, and Finsen used his eyepiece interferometer for one or two short periods on 107 nights in the continuation of his systematic search for new close pairs and the re-measurement of known pairs.

The Franklin Adams Telescope at Hartbeespoort was used by Bruwer on 29 nights and 192 plates were obtained, mainly of minor planet fields. A few plates were also taken with the Franklin Adams Twin Telescope by Churms for miscellaneous purposes.

With the 9-inch and Franklin Adams Twin Telescopes, 107 occultations of Nautical Almanac and fainter stars were observed by Churms, Knipe, Brickett, Botham and Bruwer ; predictions for the fainter stars were supplied by Lagerweij, Overbeek, Knipe, Johnston and Pikoos.

Photo-electric photometry was carried out by Knipe with the 9-inch telescope on 36 nights (minor planets and variable stars) and by Churms on 11 nights with the 6-inch photovisual component of the Twin Telescope. Bruwer tested his photometer on several nights with promising results.

Physical observations of Jupiter, Saturn, Venus, the Moon, and comets were made on 79 nights, principally with the 9-inch telescope, by Brickett, Botham and Churms.

International Geophysical Year.—Apart from service on committees, the Observatory's participation was necessarily on a restricted scale. A Moonwatch team was organized under the leadership of Williams and Botham and 22 Moonwatch telescopes were constructed, using optical components of the recommended type supplied by the South African National Committee for the I.G.Y. The launching of the Russian satellites brought the team into almost immediate operation and the rocket " casings " were usefully observed on 32 occasions ; doubtful sightings of the satellite of Sputnik I were obtained on two occasions. Nine successful photographs of the " casings " were obtained by Finsen, and one by Churms. Predictions for Moonwatch teams were supplied by Finsen.

At the end of the year the Markowitz Moon Camera had not yet been brought into operation.

Time service.—Seligmann was in sole charge of the Time Service throughout the year, with occasional assistance from other members of the staff, and activities were therefore limited largely to maintenance. He found time, however, to design and build a motor-driven mains voltage stabilizer with a rating of 2 KVA and accuracy of better than $\frac{1}{2}$ per cent for supplying all critical units of the time installation, and a console centralizing switching and display apparatus for comparing all clocks with radio time signals.

All-electronic timing devices using cold-cathode valves were made by Hers and run on test with a view to eventual substitution for the phonic motors at present in use.

The Post Office installed a 100 Mc transmitter to serve as a radio link with the P.O. Transmitting Station at Olifantsfontein for the dual purpose of supplying time signals to the artificial satellite tracking station and for the high-power transmission of time signals and standard frequencies in the near future.

Publications.—Union Observatory Circular No. 116, with contributions by van den Bos, Bruwer and Finsen, and four time signal and standard frequency bulletins were issued during the year. A note by Finsen on New Double Stars appeared in *M.N.A.S.S.A.*, Vol. **16**, No. 9.

Civil Astronomy.—The numerous routine duties under this head continue to expand at the expense of research.

The Observatory was open to the public on 23 nights ; here, again, members of the Astronomical Society lent invaluable help to the staff as demonstrators and guides.

Radcliffe Observatory, Pretoria

(*Director, Dr A. D. Thackeray, Radcliffe Observer*)

1. *Equipment.*—The Coudé spectrograph, constructed, except for a Bausch & Lomb 6×8 inch grating, by Messrs Cox, Hargreaves and Thomson Ltd., has been completed and tested, and is expected to be received in Pretoria early in 1958.

The performance of the photo-electric photometer at the Cassegrain focus has been greatly improved ; accessory apparatus now includes an integrator, timer, programmer etc. acquired from the Yerkes Observatory.

The aluminising tank for the 74-inch mirror was found during tests to suffer from certain defects which are being made good by the makers, Vecor of Vanderbijl Park.

2. *Spectroscopy.* (*a*) *Radial velocities.*—Work on radial velocities of distant B type stars is being continued, but with greater emphasis on certain clusters and associations, notably NGC 3293, IC 2944 and NGC 6067.

A programme on radial velocities of southern Me variables is essentially complete observationally, except that during 1957 a few additional stars have been added to the list at the request of the Leander McCormick Observatory.

18 spectra of 4 southern RR Lyr variables have been obtained. This work is likely to be extended in 1958.

(*b*) *Globular clusters.*—The material on globular clusters now includes 95 spectra (86 A/mm) of 17 clusters with unknown velocities and 33 spectra of 10 clusters with previously measured velocities. Three further clusters with unknown velocities have been observed with the Newtonian spectrograph. A new analysis of the cluster velocities will be undertaken shortly.

In a report to the 1957 Rome Semaine on Stellar Populations spectroscopic and photometric evidence was presented that the distance modulus of 47 Tuc (14·7) derived by Shapley is about a magnitude too large, and further that the cluster should not be regarded as an example of extreme Population Type II. The two known short period variables (HV 810, 814) in the field of the cluster are being examined for possible membership.

(*c*) *Magellanic Clouds.*—A preliminary HR diagram of the brightest members of the Large Cloud was presented to the 1957 Rome Semaine on Stellar Populations. A striking feature of the diagram is the slope upwards and to the right shown by the branch beginning with O type at about 12 m to the supergiant A and F stars at about 10 m ; this accords with current theories of evolution of massive stars.

Spectra of some 80 bright members of the Large Cloud are now ready for study. Observations have begun of emission objects in the Small Cloud utilising the lists of Henize and Lindsay. Work also continues on NGC 371 and 30 Dor (stars and nebulosity).

(*d*) *Individual stars.*—Observations of radial velocities of components of southern visual binaries are reported in a paper to appear in *Monthly Notices.*

HD 224113 : an orbit of this spectroscopic binary has been derived and will be published in *M.N.A.S.S.A.*

HDE 326823 : further spectra of this hot emission object have been obtained.

AL Vel : velocities of one component of this eclipsing variable have been measured.

AR Pav : a series of spectra of this interesting eclipsing variable was obtained through the minimum of 1957.

RR Tel : observations of the bright-line spectrum show continued increase in the state of ionization ; in 1957 Fe VI showed considerable strength.

3. *Direct photography.*—Work has been concentrated mainly on the Magellanic Clouds, the clusters NGC 1866, 1978 and 2257 receiving greatest attention. More plates have been taken near the Small Cloud for nebular counts.

Periods and light-curves of five variables in the globular cluster NGC 121 in the Small Cloud have been derived on the basis of visual estimates on 82 deep plates. Three variables have short periods (0·50 to 0·64 days) and conform to the usual pattern of light-curves in globular clusters. The other two are red and have periods greater than 100 days. Four other faint short-period variables in the vicinity of the cluster may perhaps represent the first known instances of RR Lyr variables in the general field of the Small Cloud.

More variables have been discovered in NGC 1466, the total number now standing at 45.

In a search for variables in a dense central region of the Small Cloud the total now found is about 50 of which about half are not in Harvard lists.

A series of short exposures on 47 Tuc has been taken to derive the period of HV 810.

4. *Photo-electric photometry.*—3-colour photometry of B stars in the Galaxy was continued and a good agreement for stars observed in common with Hiltner was achieved. Standard magnitudes were based on Cape Mimeogram 3 ; a small difference in zero-point from the Cape system is unexplained. This work and that on clusters IC 2944 and NGC 6067 is closely linked with spectroscopic programmes. Two other clusters, NGC 3532 and NGC 4103, have also been selected for work on account of their each containing a variable star.

Polarization measures in the halo surrounding Eta Car with a diaphragm as small as 2″ of arc in diameter confirmed the presence of strong polarization found photographically and showed that in general the electric vector is perpendicular to the radius vector to the star. The effect of polarization introduced by the flat has been studied.

Measures of the eclipsing variable AR Pav were made during the 1957 minimum.

Measures of HV 814 near 47 Tuc confirmed the presence of short-period variations with a photographic range of about 0·5 m. With the newly acquired integrator the sequence for stars in 47 Tuc was strengthened. Considerable progress has been achieved in reducing data for a colour-magnitude array of 47 Tuc. In conjunction with spectroscopic work on globular clusters a few of the brightest stars in NGC 4372 have been measured.

In the Magellanic Clouds a sequence near NGC 1466 is being set up for a study of the colour-luminosity array. Other work in the Clouds includes : (1) a comparison of colours of the globular clusters with those in the Galaxy, (2) measures of colours and magnitudes of bright stars (B types and others) in both Clouds, (3) S Dor.

5. *Analysis of Radial Velocities.* Following publication of the Observatory's second list of velocities of southern O and B type stars (*Mem. R.A.S*, **68**, 1,

1957), a catalogue of 314 stars of type B5 and earlier, with well determined velocities and with distances greater than 1 kpc, based on MK classifications and photoelectric magnitudes and colours, has been compiled. The velocities have been analysed and yield a value of the Oort constant $A = 17{\cdot}5 \pm 1{\cdot}5$ km/s/kpc, and a distance to the centre R_0 between the approximate limits 7·5 and 11·5 kpc has been derived with a most probable value 8·9 kpc. A negative K term is found for the region 1 to 2 kpc, but there is no evidence of a general contraction of the whole Galaxy. These results and other topics such as the scale of the MK system for early B stars, velocity dispersion and the ratio of the axes of the velocity ellipsoid are included in a paper communicated to the Society.

6. *Guest Investigators.*—In addition to the usual allocation of one-third time to the Royal Observatory, Cape, A. M. J. Gehrels of Indiana used the 74-inch telescope to observe light-variations photo-electrically in 3 Trojan asteroids.

7. *Buildings and grounds.*—In past years leakages have occurred during heavy rains in the basement below the Office. Extensive trenching operations seem to have finally cured the trouble.

8. *General.*—The season was the worst for many years, with unusual storms occurring in June and July. The telescope was used on 266 nights during the year.

The Observer attended the Rome Semaine on Stellar Populations in May and the Stockholm Conference on Coordination of Galactic Research in June 1957.

Comet Arend-Roland was observed visually in twilight on the mornings of April 10 and 12 near perihelion. On the latter occasion it was picked up 3° above the horizon with the Radcliffe reflector ; an attempt to secure spectra failed owing to the brightness of twilight.

A moonwatch team of amateur astronomers, led by R. Smith of C.S.I.R., Pretoria, and assisted at times by Observatory staff, observed the artificial satellites (rockets only) Sputnik I and II within the Observatory grounds, observations being communicated to the Union Observatory, Johannesburg.

8. *Staff and visitors.*—Dr T. D. Kinman worked throughout the year at the Observatory, his Radcliffe Fellowship having been extended for one year from 1957 October.

C. Jackson, Research Assistant, resigned in April in order to return to the Yale–Columbia Southern Station, Canberra.

Visitors using the 74-inch telescope were as follows : From the Royal Observatory, Cape : A. W. J. Cousins, D. S. Evans, J.v.B. Lourens, A. Menzies, T. W. Russo, P. A. Wayman (seconded from Royal Observatory, Herstmonceux). From Goethe Link Observatory, Indiana : A. M. J. Gehrels.

Other visitors to the Observatory during the year included F. Bertiau, R. Deurinck, Baron de Vos van Steenwijk, I. Epstein, K. G. Henize, H. and T. Knox Shaw, K. Rohlfs, J. Stock, R. H. Stoy, F. W. Tripp, A. van Hoof, P. Wild and astronomers from the Union Observatory and the Leiden Southern Station.

Nizamiah Observatory, Hyderabad

(*Director, Dr Akbar Ali*)

Astrographic equatorial.—The 8-inch photovisual object glass of the astrographic telescope was put into use here after re-figuring in England. It showed,

however, some defects due to slight displacement of the components during transit. It was sent back to England for re-adjustment in December 1957.

The work of deriving proper motions of stars in the regions common to the Oxford astrographic catalogues and the Potsdam Himmelskarte catalogues (zones $+32°$ and $+33°$) continued during the year. A list of 358 relative proper motions with corrections for reduction to absolute motions has been prepared by S. Aravamudan. Two more lists containing 1356 proper motions from a comparison of about 9900 stars in 56 common regions from R.A. 11^h55^m to R.A. 18^h58^m in the same zones were prepared by A. N. Goyal, Research Scholar from the Rajasthan University.

The proper motions and the mean parallax of the cluster M 38 were obtained by S. Aravamudan from a comparison of the Potsdam plate 677 (epoch 1895.123) and the Hyderabad astrographic plate 3235 (epoch 1932.088).

Grubb equatorial.—17 occultations of stars by the moon were observed and communicated to the Nautical Almanac Office for inclusion in the Annual discussion.

13 micrometrical observations of the position of the comet Arend-Roland (1956h) were made by B. Narasimhan and the positions were communicated to the Central Bureau, I.A.U., Copenhagen.

The renewal work at the domes was completed by the local P.W.D.

Spectrohelioscope.—The Observatory is participating in the I.G.Y. programme in observations of solar flares and related phenomena. The observational work at the spectrohelioscope increased very much on this account.

The Sun's disk was observed in Hα on 268 days for about 2^h50^m on average per day. 77 flares were observed. Their distribution in importance was 1 in 3, 1 in 2+, 15 in 2, 53 in 1+ and 1 and 7 in 1−. 67 dark filaments with 31 shifts towards violet, 29 towards red and 7 towards both were also observed. 30 prominences with 14 shifts towards violet, 13 towards red and 3 towards both were noted.

The data of solar observations have been communicated to the three World Centres at Colorado, Meudon and Moscow.

Spectrohelioscopic observations were taken by Habeeb Alvi for 400 hours, by Ghouse Mohiuddin for 195 hours, by B. Narasimhan for 125 hours and by Mahomed Ghouse for 35 hours during the year. The sky conditions were not wholly favourable.

The transit of Mercury over the Sun's disk on 1957 May 6 was observed by Mahomed Ghouse and the observed data were communicated to the Central Bureau, I.A.U., Copenhagen.

Publications.—The following papers were sent for publication or made ready for the press :

(1) " Stars with large proper motions in the astrographic zones $+32°$ and $+33°$, List II " (accepted for publication in the Journal des Observateurs). (2) " List of photographic double stars in the astrographic zones $+32°$ and $+33°$ having common proper motions " (ready for press). (3) " Stars with large proper motions in the astrographic zones $+32°$ and $+33°$, List III " (ready for press). (4) " Note on the proper motions of the cluster Messier 38 (NGC 1912) " (ready for press). (5) " Stars with large proper motions in the astrographic zones $+32°$ and $+33°$, List IV " (ready for press).

Equipment.—The gearing required for the construction of a new electric driving mechanism for the 15-inch Grubb arrived in March 1957. The drive has now been constructed locally and is performing satisfactorily.

In connection with the scheme of modernizing the equipment of the Observatory during the 2nd Five Year Plan of the Government of India, orders to the extent of $150,000 for equipment, including a 48-inch parabolic reflector with accessories and other auxiliary instruments, have been placed in U.S.A. The contract for the construction of the telescope is being negotiated with J. W. Feckers, Inc., through the India Wheat Loan Office.

A few workshop machines were purchased and installed during the year.

Miscellaneous.—A. N. Goyal, M.Sc., of Pilani College, Rajasthan University, was deputed to the Observatory for training in astronomical research work. During his sojourn here, from 1957 April 2 to 1957 October 11, he took up proper motion work as mentioned above.

Kashinath Nandy, M.Sc., of the Presidency College, Calcutta, also had training in astronomical work at the Observatory for a month.

Lectures in practical astronomy were delivered to the graduate classes of the Osmania University.

The other routine work, such as preparing the official calendar, seismological work, etc., continued as usual. The Observatory is cooperating in the I.G.Y. programme in seismological work also.

Kodaikanal Observatory, Kodaikanal

(*Director, Dr A. K. Das*)

General.—Sir Harold Spencer-Jones, formerly Astronomer Royal and at present Secretary-General, International Council of Scientific Unions visited this Observatory on 1957 January 26.

Intensive observations (solar, geomagnetic, ionospheric, ozonic, auroral and meteorological) were commenced on 1957 June 1 in preparation for the programme of observations which this observatory will carry out during the I.G.Y. Particulars about the solar observations were sent to the appropriate World Data Centres every month from 1957 July 1. Ionospheric data including *f*-plots for Regular World Days and Special World Intervals were prepared for transmission to the World Data Centres. Quick-run magnetic records of Horizontal Force were also made on the above days, and complete magnetic data from 1957 July 1 were kept ready for transmission to the concerned World Data Centres.

The latest recommendations of the Special Committee on World-wide Ionospheric Soundings, on scaling of ionospheric data and use of symbols and terminology, were adopted from 1957 January.

The new I.G.Y. code was brought into use from 1957 June for the duration of the I.G.Y. instead of the previously-used URSI code for daily broadcasts of Kodaikanal observations by the All-India Meteorological Broadcasting Centre. From the same date, plain language messages relating to solar and geomagnetic observations made at Kodaikanal were sent daily to New Delhi for inclusion in the special broadcasts by the All-India Radio for the I.G.Y.

Final orders for a coronagraph for this Observatory were placed with Messrs Reosc, Paris ; good progress had been made in the construction of the instrument by the end of the year.

Two sets of Askania magnetic variographs were received from the Askania-Werke, Berlin and tested for installation at the I.G.Y. field-stations at Chidambaram and Trivandrum in South India.

During the year two new Comets—Comet Arend-Roland and Comet Mrkos made their appearances. Visual and photographic observations of these comets were made whenever weather permitted.

An observational watch was kept during October and November for sighting the Russian Earth Satellites 1 and 2 and also for receiving the radio signals from them. The signals were received from the satellites on several occasions, but the satellites were never seen.

A list giving details (exposure, emulsion type, filter, etc.) of photographs of Mars and a few sketches made at Kodaikanal during the 1956 opposition, and some conclusions that could be drawn from these observations, were sent to the International Mars Committee.

Abstracts of papers contributed from this Observatory which have been published since the last general assembly of the I.A.U. were sent to the Presidents of the appropriate Commissions of the Union.

Scientific cooperation.—Exchange of spectroheliograms with foreign observatories was continued as in the previous years. 68 K-disk spectroheliograms for the period 1957 October–1957 December were sent to the Cambridge University Observatories. For the period 1956 July–1957 June 6 H-alpha disk and 7 K disk spectroheliograms were received from the Meudon Observatory and 51 H-alpha disk, 60 K disk and 82 K prominence spectroheliograms from the Mt Wilson Observatory, U.S.A.

Copies of daily spectroheliograms (disk in H-alpha and K and limb in K) were supplied in fortnightly batches to the Fraunhofer Institute, Germany, for the preparation of daily solar maps.

Three photoheliograms together with the relevant zero plates for certain specified days in 1957 were supplied to the Astronomer Royal, Royal Greenwich Observatory, England.

Quarterly statements relating to solar flares were sent, as in previous years, to the Meudon Observatory, France, and to the Royal Greenwich Observatory, England.

Periodical statements of data of solar flares, relative sunspot numbers, ionospheric parameters and sudden ionospheric disturbances, and information relating to central meridian passage of prominent sunspots and forecasts of expected magnetic and ionospheric disturbances were supplied to a number of interested institutions of India.

The practice was continued of supplying monthly median values of F2-layer critical frequency and maximum usable frequency factor for 3000 km transmission to the Central Radio Propagation Laboratory, National Bureau of Standards, U.S.A. and quarterly statements of monthly median values of all ionospheric parameters to the above institution and to the Radio Research Station, Slough. Magnetic storm data were sent every quarter to Professor John A. Simpson of the University of Chicago. Mean hourly values of horizontal force at Kodaikanal between $15^{h}00^{m}$ and $24^{h}00^{m}$ U.T. were sent

every month, beginning from 1957 May to Professor J. Bartels, Göttingen, Germany, in connection with the Equatorial Ring Current Project.

Routine observations.—Photoheliograms were made on 282 days and visual observations were possible on 278 days as compared to 309 and 305 days respectively in 1956. H-alpha disk, K-disk and K-prominence spectroheliograms were secured on 261, 259 and 258 days as against 301, 293 and 267 days respectively in the previous year. Observations with the spectrohelioscope were made on 253 days.

The average definition of the Sun's image on a scale in which 1 is the worst and 5 the best was 3. There were 39 days on which the definition was 4 or better.

Sunspot activity.—Sunspot activity continued to increase during the year. The mean latitude (for the year) of all the observed spotgroups in the northern and southern hemispheres was 19°·2 and 18°·9 respectively as against 24°·6 and 21°·0 for the previous year. Details of sunspot observations are given in the following table :—

Month		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
No. of new spot-groups	N	16	13	17	20	9	10	13	13	12	28	16	23	190
	S	13	15	17	19	17	11	12	22	17	15	14	24	196
Mean daily no. of spot-groups		7·52	6·81	7·32	8·27	6·76	6·87	7·89	7·33	7·37	10·17	9·50	9·79	7·79
Kodaikanal daily relative sunspot number		122·9	101·0	114·5	126·4	109·4	122·4	123·0	123·4	171·3	210·8	198·4	202·5	143·8

Solar flares.—24 solar flares were observed during the year, 16 of intensity 1, and 8 of intensity 2.

Radio astronomy.—Work in connection with the installation of a 10 cm radiometer was in progress.

Geomagnetic observations.—Continuous photographic recording of *H*, *Z* and *D* with Watson and La Cour magnetographs and visible recording of *H* with an Askania Field-Balance were continued. Values of *H*, *Z* and *D* were determined weekly with Q.H.M. Nos. 254, 255 and 256 and a B.M.Z. Absolute measurements of *H* with the Kew Magnetometer and those of inclination with an Earth-inductor were also made once every month.

During the year under review 32 magnetic storms, including 25 storms of SC type, were recorded with ranges in H.F. between 165γ and 708γ.

Ionospheric observations.—Round-the-clock ionospheric observations and the recording of field-intensity on two frequencies were continued. Intensive ionospheric observations were also made according to the I.G.Y. schedule.

Cosmic ray.—Photographic recording of cosmic ray intensity was continued using a Kolhörster cosmic ray apparatus.

Ozone.—Regular observations of atmospheric ozone were made with the Dobson spectrophotometer.

Seismology.—The Milne-Shaw seismograph (E–W component) recorded 127 earthquakes.

Meteorology.—Meteorological observations with all the visual and self-recording instruments were carried out as usual.

Library.—138 books and 1914 periodicals were added to the library.

Research work.—Under the Research Training Scheme sponsored by the Ministry of Education, Government of India, four Senior Research Scholars were working in the Observatory.

The following problems in astrophysics and geophysics were under investigation :

1. Determination of absolute values of the wavelengths of solar spectrum lines in order to determine how much of their red-shifts can be accounted for by the theory of relativity.
2. Detection of deuterium on the Sun.
3. Study of the distribution of intensity in the various features of the Sun's disk with the help of a Moll thermo-couple and a thermo-relay.
4. Simultaneous measurement of the temperature and the magnetic field of sunspots.
5. Distribution of calcium flocculi on the Sun's disk.
6. Further study in scattering of radio-waves by ionospheric F-layer and some related geomagnetic phenomena.
7. The behaviour of night-time sporadic E-layer at Kodaikanal.
8. Disturbances in the ionospheric F2 layer associated with geomagnetic storms.
9. The relationship of ionospheric F2 layer ionic density with various features of solar activity.
10. On causes of time-lag between ionospheric sunrise and F-layer sunrise effect.

Publications.—The following papers and notes were published or prepared for publication :—

(1) " Comet Arend–Roland (1956h) ", *Journal of Scientific and Industrial Research.*
(2) " Does magneto-hydrodynamics explain certain solar phenomena better than classical dynamics ", to be presented at the proposed symposium on magneto-hydrodynamics under the auspices of the Atmospheric Research Committee.
(3) " Observations of Spread Echoes from the F-layer over Kodaikanal: A preliminary Study ", *Indian J. of Met. and Geophys.*
(4) " Quarterly synopses of results of solar, magnetic and ionospheric observations ", *Indian J. of Met. and Geophys.*
(5) Annual Report of the Kodaikanal Observatory for 1956.
(6) *Kodaikanal Observatory Bulletin No.* 145, Summary of results of solar and magnetic observations for the first half of 1955.
(7) *Kodaikanal Observatory Bulletin No.* 146, Summary of results of solar and magnetic observations for the second half of 1955 and summary of ionospheric observations from September to December 1955.
(8) *Kodaikanal Observatory Bulletin No.* 147, Summary of results of solar, magnetic and ionospheric observations for the first half of 1956.
(9) *Kodaikanal Observatory Bulletin No.* 148, Summary of results of solar, magnetic and ionospheric observations for the second half of 1956.
(10) *Kodaikanal Observatory Bulletin No.* 149, " Centre-limb variation of solar excitation temperature as derived from Ti I lines ".
(11) Reports to the Society on (*a*) the work of the Kodaikanal Observatory, and (*b*) prominence activity for the year 1956.
(12) Observations of Mars during the 1954 and 1956 oppositions, to be published as a *Kodaikanal Observatory Bulletin.*
(13) Magnetic Field of Venus, to be published as a *Kodaikanal Observatory Bulletin.*
(14) " Results of Mars Observations ", *Indian J. of Met. and Geophys.*

Uttar Pradesh State Observatory, Naini Tal

(Chief Astronomer, Dr M. K. Vainu Bappu)

Stellar spectroscopy.—Line intensities of hydrogen-like transitions in C IV measured on Mt Wilson spectrograms having a dispersion of 10 A/mm have been used to derive excitation temperatures of HD 192103 (WC 7) and HD 184738 (WC 8). The transitions 7–10, 7–12, 7–15, 7–16 having wave-lengths 5470·8 A, 4229·2 A, 3566·9 A and 3450·5 A respectively, identified recently by Edlén, can be seen well on spectrograms of the WC stars. Using values of the transition probabilities from the equivalent case of hydrogen, temperatures of 49 000° ± 10 000° for the WC 7 stars and 27 000° ± 8 000° for WC 8 stars are obtained. The application of this approach to other WC stars is limited by the fact that serious blending prevails in such stars. Using the excitation temperatures derived in this way, and the helium line intensities, b_n ratios have been calculated for the two stars. These indicate that collisional excitation may be quite dominant in the Wolf–Rayet atmosphere. The results of this investigation were presented at the Liege symposium on " Emission Line Stars " held during the year.

Line intensities and wave-lengths have been measured in the near infra-red for the stars HD 192103 and HD 192163. These were measured from Mt Wilson spectra having a dispersion of 111 A/mm, and supplement the pioneering effort of Swings and Jose in this field.

A detailed analysis of spectra, having dispersions of 10 A/mm and 4·5 A/mm, and obtained at Mt Wilson, of the 3·7 day cepheid variable RT Aurigae is in progress. The spectra were obtained at different phases and should yield much information regarding physical conditions in Cepheids of short periods. Much progress has also been made on a programme of analysis of the changes in the shell of Pleione.

Photoelectric photometry. (*a*) *Beta Canis Majoris stars.*—Observations were made on nine nights of Gamma Pegasi through a *V* filter. These used 34 Piscium and 82 Pegasi as comparison stars. On thirteen nights measures were made of 16 Lacertae. Reduction of these observations is in progress.

(*b*) *Eclipsing variables.*—As an extension of the attempts made to derive monochromatic light curves photographically for the Wolf–Rayet binaries HD 214419 and HD 193576, photoelectric observations through interference filters were carried out on twenty-two nights. These filters have a half-width of 85 A, have 35 per cent peak transmission and are chosen to isolate the He I and He II lines at 5875 A and 4686 A respectively, as well as the continuum around 5000 A. These observations demonstrate well the possibility of obtaining monochromatic light curves of precision until magnitude 9·0 with the 10-inch refractor.

Observations through *B*, *V* filters have been commenced of the following eclipsing stars: Beta Lyrae, Delta Orionis, AR Cassiopeiae, i Bootis and 29 Canis Majoris.

(*c*) *Magnitudes and colours.*—A study of *B*, *V* magnitudes and colours of thirty-seven stars in the galactic cluster in Coma Berenices is nearly complete. The observations were obtained on ten nights. A few more observations are

required for deriving a reliable zero point in the cluster. Some observations were also made of stars in the galactic cluster Messier 7.

(*d*) *Miscellaneous.*—A programme of research for light variability of selected stars is being initiated. A few runs during the year were made of the two F supergiants, 6 Cassiopeiae and Phi Cassiopeiae as well as of the Of star Zeta Puppis.

On two nights, continuous runs for some time were made of Nova (V603) Aquilae (1918), R Aquarii and Omicron Ceti, in order to study the short period fluctuations discovered recently in these stars.

Observations were also obtained of the short period variable Rho Puppis in two wavelengths, one centred on 4050 A and the other around 6100 A.

The solar system.—Polarization measures of the nuclei of Comet Arend–Roland (1956h) and Comet Mrkos (1957d) have been carried out photoelectrically. The observations were made through interference filters that transmitted the Swan bands, sodium D-lines and the continuum, as well as through standard *B*, *V* filters. In the case of Comet Arend–Roland a mean value of twenty per cent polarization at phase angle equal to 90° was obtained. The nucleus had a colour equivalent to that of a K2 V star. The polarization results obtained in the case of Comet Mrkos are identical with those of Comet Arend–Roland, except that a high value of polarization was obtained through the 5890 A filter on two nights, caused probably by the presence of strong sodium resonance radiation.

Airglow and aurorae.—The Observatory is one of the stations in India partaking in a visual search for aurorae during the I.G.Y.

An investigation is in progress regarding the diurnal variation characteristics of the airglow emission lines. The measures are carried out photoelectrically using narrow band filters that isolate the emission lines as well as the continuum. This project is supported, in part, by a grant from the Council of Scientific and Industrial Research.

Equipment.—The fused quartz 10-inch optical flats as well as 10-inch off-axis paraboloid ordered from Messrs Cox, Hargreaves and Thomson Ltd. for a horizontal solar telescope have arrived. An order has been placed with the same firm for a 4·5-inch lens to be used as objective in a Littrow medium-dispersion spectrograph. The spectrograph will use a Bausch and Lomb grating blazed in the first order at 1·6 microns. Messrs Cox, Hargreaves and Thomson have also supplied a synchronous motor drive for the 10-inch refractor. An order has been placed with Messrs Bernhard Halle Nachfl of Germany for an H-alpha birefringent filter.

Some equipment for the electronics shop and machine shop was acquired during the year.

Buildings and roads.—The year has witnessed much progress in construction work on Manora Peak. The one mile approach road to the top of the peak as well as buildings for the electric substation and the workshop were completed by June. The main administrative block, which will house the offices and laboratories, is under construction.

Staff.—Mr Subhash Chandra, Research Assistant, went on leave of absence to spend the academic year at the University of Lucknow. Messrs P. K. Jain and C. D. Kandpal were appointed Research Assistants. Messrs N. B. Sanwal and M. C. Pande were appointed to two newly-instituted research fellowships at

the Observatory. Mr Pande resigned his fellowship in December in order to accept a position of Senior Scientific Assistant at the Observatory on a C.S.I.R. scheme.

Visitors.—Visiting scientists have included Dr J. A. Hynek (Smithsonian Astrophysical Observatory), Mr F. J. Kerr (Radiophysics Laboratory, Sydney) and Dr S. Gaposchkin (Harvard College Observatory).

Mount Stromlo Observatory of the Australian National University
(*Director, Professor Bart J. Bok*)

1. *Transfer of Observatory.*—The date of 1957 January 3, will remain an important landmark in the history of Australian astronomy. On that day the Commonwealth Observatory of the Department of the Interior ceased to be and the Observatory was transferred by Act of Parliament to the Australian National University. The members of the Observatory's scientific staff were all transferred to the Department of Astronomy of the Research School of Physical Sciences of the Australian National University and the Observatory's name became officially: *Mount Stromlo Observatory.*

2. *Staff and visitors.*—Following the departure of Dr R. v. d. R. Woolley (1955 December 7) Dr A. R. Hogg assumed the post of Acting Director of Mt Stromlo Observatory, and he served in this capacity until Dr Woolley's successor, B. J. Bok, took office on 1957 March 7. Dr Hogg's period of service as Acting Director covered the difficult time of transfer and much credit should be given to him for the smoothness with which the whole transaction was handled. Upon his arrival in Canberra, Bok became the Head of the newly-formed Department of Astronomy at the Australian National University. Dr Hogg, already a Reader in the Australian National University, was appointed to the post of Assistant Director. During 1957 Dr Woolley was appointed an Honorary Professor in the Department of Astronomy.

The principal new staff appointment of 1957 was that of Dr Theodore Dunham Jnr to the post of Reader in Astronomy. Mr H. J. Abraham was promoted from the rank of Fellow to that of Head of the Time Service with the equivalent rank of Senior Fellow.

Dr S. Gaposchkin came in the middle of 1956 as a visitor from Harvard Observatory, and he returned to the United States early in June, 1957. In 1957 July Dr F. B. Wood, Professor of Astronomy at the University of Pennsylvania, came to Mt Stromlo on a Fulbright Fellowship. He is expected to remain at the Observatory until the middle of 1958. There has been a steady flow of visiting scientists from Australia and abroad. We have especially welcomed visits from staff members of the Radiophysics Laboratory of the C.S.I.R.O. in Sydney, with whom we seek close collaboration in many areas of research of common interest.

The Mt Stromlo Observatory is host to two foreign establishments, the Stations of the Yale-Columbia and Uppsala Observatories. For the sake of completeness we summarize here the staff changes at these two stations. In 1957 March, Dr G. de Vaucouleurs resigned as Yale–Columbia Observer to take a position at Lowell Observatory in Flagstaff, Arizona. He was succeeded in 1957 May, by Mr C. Jackson. In 1957 July, Dr I. Epstein arrived at the Yale–Columbia Station, and as a guest at Mt Stromlo Observatory, to take charge of

the Yale–Columbia Site Testing Expedition sponsored by the U.S. National Science Foundation. The Uppsala Observer, Dr B. E. Westerlund, and Mrs Westerlund, arrived at Mt Stromlo in 1957 June, and have since been in residence.

3. *Instrumental development.*—Dr Hogg completed his tests of the 74-inch mirror, which proved conclusively the presence of astigmatism in excess of the maximum permissible amount. Steps are being taken to remedy this situation, but in the interim the telescope is serving very well for photoelectric, spectrographic and to a considerable extent for photographic work.

The overhauling of the 50-inch Reflector has proceeded with highest priority. Motorization of the Right Ascension Fast Motion and Clamp has been completed and provisions have been made for Selsyn Repeater Systems in Declination and Right Ascension. The Polar Axis has been fitted with ball bearings. The new electrical system is almost ready for operation. An aspherical gregorian secondary has been completed by Dr S. C. B. Gascoigne and Mr P. Alexander, which, when combined with the spherical $f/2$ primary, yields a field of good definition sufficiently large for photoelectric work. Plans are under way, however, to replace the present primary with an $f/4{\cdot}5$ paraboloid and a conventional cassegrain mirror for the entire system to operate at $f/18$.

An 8-inch $f/1$ Schmidt camera of Meinel–Pearson design arrived from Yerkes Observatory, after testing at Harvard Observatory, and is now mounted on the Farnham Refractor.

The adjustment, testing and placing into full-scale operation of the Zeiss–Newtonian Spectrograph on the 74-inch Reflector is proceeding. In 1957 July, the direction of the work was transferred from Dr W. Buscombe to Dr H. R. F. Gollnow. The spectrograph is producing fine spectra for luminosity classification, but certain difficulties have still to be resolved with temperature control for precision radial velocity work.

Four standard photoelectric photometers with interchangeable electronic components will soon be in operation at Mt Stromlo Observatory. Dr Wood brought with him on a much appreciated long-term loan to Mt Stromlo Observatory an amplifier constructed by Dr William Protheroe of the University of Pennsylvania. The instrument feeds a conventional recorder and simultaneously serves as an integrator; after a set time interval the integrated signal is recorded. Rapid impersonal reduction of each observation is thus achieved, while the observer can still see the actual tracing for each star.

Dr Gascoigne has supervised the construction and putting into operation of a Wide Field Photometer, built according to a design of Dr G. E. Kron. The instrument performs very well for wide-band $(P–V)$ photometry, but the sensitivity is not yet quite high enough to permit work with interference filters on H beta radiations from faint nebulae—the primary purpose for which the instrument was built.

Considerable interest attaches to Dr Dunham's plans for a coudé spectrograph on the 74-inch Reflector. The following paragraphs outline Dr Dunham's plans for the immediate future:

A coudé spectrograph is being designed by Dunham to be installed at the north end of the mounting on the 74-inch telescope, where the converging beam issues from the opening in the hollow polar axis, to form images of stars and planets at a fixed location which is convenient as a starting point for a powerful spectrograph.

The mechanical design is being developed in collaboration with Mr K. Gottlieb, and incorporates the suggestions of other members of the staff, particularly Dr Gascoigne, Dr Gollnow and Dr Buscombe. The optical design follows that of the coudé spectrograph at Mt Wilson, and is based on the use of large reflecting cameras with diffraction gratings. Steps are being taken to obtain from the Unites States a series of gratings large enough to cover a 7-inch aperture, each with a ruling designed for maximum brightness in a different region of the spectrum.

A series of three concave spherical mirrors, with focal lengths of 21, 48 and 114 inches, and with diameters of 20, 30 and 36 inches, are being loaned by the Fund for Astrophysical Research Inc. in New York for use in the reflecting cameras. Schmidt correcting plates will be made from ultraviolet transmitting glass for the 21-inch and 48-inch cameras. The longest camera, with a focal length of 114 inches, will yield a spectrum with a linear dispersion of 2·9 angstroms per millimetre, and, with fast photographic emulsions, a spectral resolving power of approximately 70 000. It is expected that this camera will be capable of covering stars to the 6th magnitude with exposures that can be accomplished in a single night. An 8-inch Schmidt camera will be used for photographing the spectra of faint stars with a dispersion of about 40 A/mm and with high efficiency. At the start the Meinel–Pearson $f/1{\cdot}0$ Schmidt camera already available at the Observatory will be used to test the performance of this system. The various cameras will be mounted on a sliding carriage, so that any one of them can be located where it will receive the spectral beam from the grating.

The spectrograph will be enclosed in a housing with double walls, 24 ft long (in the north–south direction) and 16 ft wide. Air at constant temperature will circulate between the two layers of the wall, thereby avoiding thermal effects on the instrument. The housing will project approximately 12 ft outside the dome.

Provision will be made for using the 114-inch camera for photoelectric scanning of stellar spectra, with the expectation that this will provide results which can usefully be compared with photographic results, and used to set up standards for absorption lines. Through the University of Rochester, the Research Corporation has provided pulse-counting equipment and the National Science Foundation has provided an extremely stable D.C. amplifier for this programme. The University of Rochester has in addition loaned much optical and electronic equipment.

In order to test the performance of a 114-inch camera on bright stars and the performance of an 8-inch camera on faint stars with the minimum of delay, a simple spectrograph will be built as quickly as possible on a steel frame, without more than simple accessories. It is hoped that this spectrograph can be in operation by the middle of 1958, and that parts of the final instrument can be installed, step by step, without interrupting the observing schedule.

4. *The National Time Service.*—By the arrangements under the Act of Transfer, the University " undertakes that it will continue to operate the Observatory . . . including the Time Service . . .". It seems indeed fitting that this be the case. Not only is it a fine tradition that the largest observatory of a country should have under its wings the National Time Service, but the presence of the Service in a University observatory provides day-to-day contact for staff and students with the precision techniques of measurements of time and positions

—an art that is only too easily ignored in an observatory where the primary emphasis is on astrophysical studies and research on the Milky Way system and other galaxies.

The traditional activities of the Time Service have been continued and in addition several are being extended in connection with the International Geophysical Year. The installation and placing into operation of the Photographic Zenith Tube is taking much of the staff's time. With the arrival of three new staff members an extensive programme of training has been initiated.

By reason of our geographical position, observations of longitude and latitude by this Observatory are specially needed for the International Geophysical Year programme. Mount Stromlo is the most southern observatory to send its results regularly to the Bureau International de l'Heure. Twenty-nine such observatories operate north of 30° N but for the rest of the world there are only Mt Stromlo and two observatories in South America. Accordingly, since the start of the I.G.Y. in July, the normal evening transit observations have been increased by an equal number taken after midnight. The results are reduced and reported to the Bureau.

The Photographic Zenith Tube has been adjusted and tested and has been in operation nearly every night in November and December. The purpose of the present observations is to establish a self-consistent system of star places from which to determine time and latitude variation. Final checks are being made to test the performance of the instrument and of the measuring engine for the PZT photographs. A Markowitz Dual Rate Moon Camera has been received on loan from the U.S. Naval Observatory, and is being installed. This instrument is designed to determine uniform time.

As in previous years, time signals were sent out from the Observatory four times each day for transmission by Belconnen Naval Wireless Station. Signals from clocks at the National Standard Laboratories, Sydney, the Post Master General's Research Laboratory, Melbourne and the Post Office, Adelaide, were measured regularly and corrections reported. Radio signals from foreign observatories were measured daily and reports are issued regularly listing differences between observations.

5. *Progress in research.*—We have already noted *Dr Hogg's* activities in connection with the tests for the 74-inch mirror. His principal research activities continue to be in the study of star clusters—notably a combined photographic and photoelectric three-colour study of κ Crucis and a similar research for NGC 330 in the small Magellanic Cloud. Research on standard magnitudes is approaching a conclusion for 250 southern stars—all measures being on the Johnson–Morgan U, B, V system. In addition a U, B, V sequence is being established in the Small Magellanic Cloud.

Dr Gascoigne has concentrated his research activities on globular clusters and the Magellanic Clouds. Two-colour light curves have been obtained for three variables in ω Centauri and some red giants were observed in 47 Tucanae (at the request of Dr Westerlund). Several clusters not hitherto searched for variable stars have been photographed with the 74-inch Reflector and a programme has been started to determine magnitudes, colours and central brightnesses of southern globular clusters. Earlier photoelectric work on cepheids in the Magellanic Clouds has been continued and—with the aid of the 74-inch Reflector—this research has been extended to a few stars with periods less than 10 days. Finding

charts for the Magellanic Clouds are being prepared in collaboration with *Miss Helen Bailey*, Mr A. W. Rodgers and Dr Westerlund from photographs made with the Uppsala Schmidt Telescope. Special stars made the subject of photometric study include the galactic cepheid BB Sagittarii.

Dr Dunham has so far been concerned principally with the design problems of the coudé spectrograph. He is working on the preparation of a catalogue comprising all information available for the spectral characteristics of all southern hemisphere stars brighter than $m = 7{\cdot}0$ and to $m = 10$ for B and A stars.

Dr Gollnow is continuing his long-range studies of radial velocities for the Scorpio–Centaurus cluster and for stars in the FK 3 and N 30 catalogues. With the Zeiss 2-prism spectrograph, 24 spectra have been obtained for members of the θ Carinae cluster and spectra of 75 stars have been obtained for the purpose of testing the instrument for radial velocity work. *Miss Margaret Curry* assists in the measurement of Dr Gollnow's plates.

Dr G. Hagemann collaborates with Dr Gollnow in the execution of the measurements and reductions for most of the above programmes. In addition, he has made a study of the spectroscopic binary ζ Phoenicis. The measurements are complete and the reductions are in progress.

Dr Buscombe and Miss P. Morris are collaborating in the execution of their share in 30-inch programmes for radial velocities of the Scorpio–Centaurus Cluster and stars in the N 30 catalogue. Work is continuing on spectroscopic binaries, with eight of these presently on the preferred list. The study of δ^7 Telescopii is practically finished. Dr Buscombe is participating in the world-wide cooperative programme for the study of θ Ophiuchi, which is being coordinated by Professor van Hoof of Louvain. A Finding List of High Velocity Stars for the southern hemisphere (1315 entries) has been completed. Dr Buscombe and Miss Morris coordinate the work on spectral-luminosity classification of southern stars under way with the Zeiss–Newtonian spectrograph on the 74-inch Reflector. A list has been prepared of 150 stars south of declination $+30°$ for which W. W. Morgan has determined spectral-luminosity classes and these are being photographed with a dispersion of 90 angstroms per millimetre at Hγ. As an aid to classification, microphotometer tracings are being made of many spectra. Dr Buscombe and Miss Morris are initially concentrating their efforts on the region of the South Galactic Polar Cap. A group of suspected subdwarfs and twenty stars in the Large Magellanic Cloud are also on the present observing programme.

Dr A. Przybylski has rounded-off for the present his theoretical studies of model atmospheres. He has been active in the observation and study of the orbits of artificial satellites (see below) and he has completed his research on the orbit of Comet 1919 V (Metcalf–Borelly). He continues actively as an observer on the 30-inch radial velocity programme and is a participant in the work on spectral–luminosity classification with Dr Buscombe and Miss Morris.

Mr A. W. Rodgers has completed and revised his doctoral thesis on a three-colour study of the regions of the Southern Coalsack, following the techniques developed by W. H. Becker of Basel. The Becker method is found to be workable for faint stars when use is made of a proper blend of photographic and photoelectric techniques. Work on the thesis delayed his entering into full participation in the observatory programmes, but work is now under way on three projects: (1) spectral-luminosity classification of about 30 stars in Shapley's

Constellation III in the Large Magellanic Cloud (see also Bok, to follow); (2) photography of selected fields with the Meinel–Pearson camera; (3) a comprehensive study of selected southern OB associations.

Professor B. J. Bok has been principally active as a photoelectric observer. The programmes on which the work is well advanced are: (1) a standard sequence for Selected Area 141 (near the Galactic Pole); (2) standard sequences for Selected Areas 193 (Carina–Centaurus) and 158 (Sagittarius); (3) a check on van Wijk's Sequence in the Large Magellanic Cloud; (4) *U, B, V* colours and magnitudes for 30 stars in Shapley's Constellation III in the Large Magellanic Cloud (in collaboration with Rodgers); (5) colours and magnitudes of selected O, B and A stars in three regions in Carina–Centaurus centred on known cepheid variables. The reduction of the photometer tracings is being done by *Dr Priscilla F. Bok*, who participates in the analysis of the material. Supplementary photographic studies from Uppsala Schmidt plates are under way in collaboration with *Mrs Jane Basinski* for the region of the South Galactic Polar Cap and similar work is planned for the Carina–Centaurus and Large Magellanic Cloud centres.

Mr K. Gottlieb, Bok and Mrs Basinski are working on a joint programme of attempted optical identification of discrete radio sources south of declination $-30°$ discovered by Dr B. Y. Mills of the Radiophysics Laboratory of the C.S.I.R.O. in Sydney.

Dr B. E. Westerlund, the Uppsala Observer at Mt Stromlo, has kindly offered the following notes regarding work of the Uppsala Station during 1957. We are happy to make our Stromlo telescopes available to Dr Westerlund on an exchange basis. His report follows:

" The final adjustment of the Uppsala Schmidt telescope was carried out. The direct, and especially, the spectral plates obtained are of excellent quality. A series of observational programmes has been started. Among those almost completed may be mentioned: *Spectrophotometry*. Widened objective-prism spectra (dispersion 380 A/mm at Hγ) have been secured on blue sensitive plates of the regions of the South Galactic Pole and the Magellanic Clouds. The magnitude limit of the plates for classification in the Uppsala system is about $m_{pg} = 15{\cdot}0$ mag. Unwidened spectral plates in the near infra-red have been taken of the Magellanic Clouds, 47 Tucanae and selected regions of the Milky Way and the South Galactic Pole. The magnitude limit of the plates for classification of red giants in the Case system is about $m_{ir} = 14{\cdot}5$ mag. *Direct photometry*: Some centres in the above mentioned fields have been observed in infra-red and red for the photometry of the red giants, and in red, yellow, blue and ultra-violet for the other spectral classes. A number of plates have been taken for the Uppsala–Mt Stromlo Atlas of the Magellanic Clouds. Plates for counts of galaxies have been taken of some fields."

Dr S. Gaposchkin was an assiduous observer on the 30-inch Reynolds Reflector during his ten months at Mt Stromlo as a guest observer. He took 570 spectra, mostly on his own programme of southern stars of special interest.

Dr Wood is using principally the 20-inch and 30-inch Reflectors with an occasional night on the 74-inch Reflector. He concentrates on two and three-colour photometry of southern eclipsing variables. The observations for the Algol system TZ Coronae Australis and V Tucanae (periods less than one day) are complete and the observations for RS Leporis are under way. Three colour

work has been done for δ Capricorni and the intrinsic variable SX Phoenicis. Several other eclipsing systems are under observation.

6. *Observation of artificial satellites.*—The Mt Stromlo Observatory is *not* in any way officially involved in the observation of artificial satellites. Australian participation in the observing is well taken care of by the Weapons Research Establishment at Salisbury and Woomera and by amateur groups (notably in Sydney) coordinated by Professor L. G. H. Huxley of the University of Adelaide. When, however, Sputnik I flashed in the sky and was observable from Canberra, and with many of the official observing units not ready to operate, we had no choice but to step into the breach and do our share of observing.

Accurately-timed visual observations were made first by Mr Abraham and his associates in the Time Service and later by Dr Przybylski. Mr Gottlieb succeeded in obtaining, on the evening of October 8, a remarkable photograph with the Uppsala Schmidt Telescope. This photograph has been circulated widely. All Stromlo observations of Sputnik I refer of course to the casing; they have been useful in fixing the eccentricity of its orbit.

In recent months, Dr Przybylski has followed the satellites with care and has done considerable work on their orbits. To regularize occasional wide distribution of the results of his work, Dr Przybylski issues from time to time duplicated copies of predicted times of observation—which predictions have proved to be of gratifyingly high reliability. Dr Przybylski has completed the manuscript of a paper " On the visibility of artificial satellites with highly inclined orbits ".

7. *Site testing.*—The Mt Stromlo weather is not ideal for astronomical work. The records show that approximately one-quarter of all nights are excellent, one-quarter poor, but usable in part, and the remainder of little use. The seeing is on the whole good and does not suffer from the regular deterioration at about midnight that prevails on the high veldt of South Africa. The bad weather is distributed rather evenly and good nights occur with at least average frequency during the months January through March, when poor weather prevails in South Africa and when the Large Magellanic Cloud is high in the evening sky.

Because of the proximity of Canberra and the National University, it would be unwise to contemplate moving the Observatory to a better site—or to move any of the major telescopes. At the same time, it seems highly desirable that various potential sites in Australia be tested for transparency, number of clear nights and seeing, with a view to establishing a Field Station inside a few years.

The Yale–Columbia group has been especially concerned with this problem since they are considering the establishment of a 20-inch astrograph at a suitable site in Australia. The U.S. National Science Foundation has made a grant to Yale University to initiate a site-testing survey for Australia, and Dr I. Epstein arrived in July, 1957, to start the survey. The Mt Stromlo Observatory is much interested in this work and assists Dr Epstein in every possible way. Site-testing by the Yale–Columbia group is now in progress in W. Australia and in NW New South Wales. Consideration is being given to site-testing in other parts of Australia, notably in the Flinders Range of S. Australia.

After elimination of unsuitable sites, observations must be made for long periods at the more promising places. It is necessary that we should know where in Australia are the best locations for astronomical work. Not only is this question relevant to the Yale–Columbia plans and the Mt Stromlo plans for the future, but it is one to which a full answer must be known for the good of

development of astronomy in Australia. Dr Dunham's 70-inch coudé telescope must be placed at a first-class site and no one will consider bringing a large telescope to Australia unless the site for it has been thoroughly tested and found adequate.

8. *Symposia and colloquia.*—Since May, regular bi-weekly colloquia have been held with the attendance running as high as 30 to a colloquium. In addition several special colloquia have been interpolated.

During 1957 we held two joint Symposia with the Radiophysics group from the C.S.I.R.O. in Sydney. On May 12 and 13, the Sydney and Mt Stromlo staffs held a joint *Pre-Conference on the Coordination of Galactic Research.* The Pre-Conference had the multiple purpose of considering problems of common interest to the optical and radio astronomers, of making our views known to the International Conference to follow in June in Stockholm, and of giving our representatives to the Stockholm Symposium, Dr Hogg and Mr F. J. Kerr, our opinions regarding several topics to be discussed at Stockholm—and others omitted from the Stockholm agenda. The proceedings of the May Symposium were distributed in duplicated form as a pamphlet. The second symposium, held on October 8 at Mt Stromlo, was primarily a Post-Conference Report by Dr Hogg.

9. *Public visits.*—There have been many public visits to the Observatory during the day and night. Monday to Friday we are continuing the traditional public visits with a guide at 11^h00^m and 15^h00^m, and arrangements have been made for guided tours on Saturdays, Sundays and holidays at 15^h00^m. The Wednesday night sessions for 10 to 15 people continue to have long waiting lists. To accommodate the great demand for visits at night, we have instituted a series of monthly Visitors' Nights with an average attendance of 150 people. During the year there have been approximately 3500 daytime visitors, 500 Wednesday night visitors, and 1000 visitors during the seven special evenings. To make readily accessible to these many visitors information about the Observatory and its work, we have issued a booklet about the Observatory that is available to all who are interested.

Riverview College Observatory, N.S.W.
(Director, T. N. Burke-Gaffney, S. J.)

During 1957, in spite of phenomonally low rainfall, seeing conditions were generally poor, with the result that a smaller number of plates than usual was taken for the Variable Star programme. For the same reason comparatively few occultations were observed.

Geophysical Papers, No. 7, and Reprint No. 2 (Ser. 2) were distributed during the year, but the onset of the International Geophysical Year, with consequent increase in commitments, has retarded further the production of the " Riverview College Observatory Publications ", two volumes of which have been completed.

At different times facilities were provided for research students to carry out observations at the Observatory. Information on astronomical and geophysical matters was provided, as is customary, to various interested parties, the interest aroused in the latter part of the year by the artificial satellites, adding considerably to the time spent in this service.

Routine repairs and replacements have been rather greater this year than is usual and have had some slight effect in temporarily disorganising the regular work of the staff; this was off-set by the increase in efficiency consequent upon the improvements carried out.

Sydney Observatory

(*Director, Harley Wood, Government Astronomer*)

The work on the Astrographic Catalogue has been continued. Volume 38 of the Sydney section was published and distributed and Volumes 39, 40 and 41 are in various stages of printing. Volume 5 of the Melbourne section was printed in Paris under the direction of Dr J. Baillaud, using resources granted by the International Astronomical Union. Dr Baillaud is at present working on Volume 6 and the manuscript of Volume 7 was this year completed at Sydney Observatory and sent to him. Work is proceeding on Volume 8.

Occultations predicted in the *Nautical Almanac* have been observed when possible. The results for 1956 have been published and those for 1957 are being reduced. The observations of minor planets which culminate south of the equator has been continued. The results for 1955 and 1956 have been published and the observations for 1957 are being reduced. Observations were made of Pallas, Hebe and Iris which are among those selected for purposes of fundamental astronomy. The observation of double stars by photography using the standard astrograph has been continued. A transit of Mercury was observed on May 6 and the results published in the *Observatory*.

Dr I. Epstein of Columbia University, who is making a survey on behalf of the National Science Foundation of the United States of America to find an observatory site in Australia has been given help with the New South Wales part of his programme.

The civil and educational work of the Observatory has been carried on as in previous years.

Radiophysics Laboratory, Sydney

(*Chief, Dr E. G. Bowen*)

The radio astronomy group is under the direction of Dr J. L. Pawsey.

During 1957 the survey of the southern sky with the 85 Mc/s Mills Cross pencil-beam aerial was completed. The results confirm the previously reported disagreement with the Cambridge survey of discrete sources made with an interferometer-type aerial. For these results to be applied usefully in cosmological studies it is felt that observations of the angular size of very small sources ($< 1'$ arc) are needed. Equipment designed for this purpose is nearing completion.

The radio heliograph is now completed and daily pictures of the Sun at 20 cm are being produced. The swept frequency interferometer, designed to measure the position and angular size of solar bursts, has been extended considerably, in order to improve the accuracy. Early results show that at 40 Mc/s the sources of the bursts range in size up to one-tenth of the size of the visible Sun.

Freeman Fox of London have completed their design study for the Giant Radio Telescope which is to be constructed in Australia from funds donated by the Carnegie Corporation of America, the Rockefeller Foundation and the Australian Commonwealth Government. The chosen design calls for a 210 ft diameter paraboloid mounted in the alt-azimuth fashion on a single pedestal. A site for the telescope has been selected at Parkes, N.S.W., 200 miles west of Sydney. It is expected that contracts for the construction of the telescope will be let in the near future.

1. *Cosmic radio waves*

(*a*) *Continuous emission.*—The survey of the southern sky using the 85 Mc/s Cross (beamwidth 50′ arc) has been completed in the last year and reduction of the results is in progress. A catalogue of radio sources between declinations $+10°$ and $-20°$ has been prepared; this contains 1158 sources. Further catalogues, covering more southern regions, are planned. Analysis of the catalogue supports, in general, the preliminary results reported last year. There appears to be a small excess of faint and presumably distant sources which arises in part from instrumental effects and partly from either a real excess physical clustering of the sources, or simply a statistical deficiency of strong and close sources. Angular size data on very small sources ($< 1'$ arc) are needed before the results may usefully be applied to studies of cosmological questions. The preparation of the necessary equipment to make these measurements is in progress. The catalogue is being investigated for identifications with celestial bodies but there is little definite to report yet: the brightest nebulae in the area are, however, detectable as radio sources.

The distribution of radiation within the galaxy has also been investigated and contour maps have been prepared along a strip 10° wide stretching from longitude 233° through 0° to 13°. Three galactic components can readily be identified—the corona, the disk, and a population of strong sources closely confined to the plane of the disk. Other interesting regions and objects have been studied in detail, e.g. the Orion and Vela Puppis regions, the radio sources Fornax A, Puppis A and Centaurus A and the local supergalaxy. Papers describing these results are in preparation.

Recording time with the 19 Mc/s Cross has been limited by severe interference from radio stations, especially during summer months, but it has usually been possible to obtain a few hours of good records during the early morning hours. Effort has been concentrated on accumulating sufficient observations for a detailed study of the absorbing band of H II regions around the galactic equator, the detection of which was mentioned in the last Report. The analysis of these observations is now proceeding.

The 19 Mc/s Cross has sufficient resolution to permit the detailed study of the brightness distributions of several discrete sources and, in particular Centaurus A and the Magellanic Clouds have been studied. In each case there are significant differences between the observational results from the 85 Mc/s and 19 Mc/s equipments.

Observations of a number of discrete sources have given measurements of ionospheric refraction and its variability. Such information is essential for the reduction of low frequency observations and should also be useful for ionospheric studies.

(*b*) *Hydrogen line studies.*—Complete observational results from an extensive survey of 21 cm line emission near the galactic plane are being prepared in a form suitable for publication. Conversion of the data to point-by-point hydrogen densities throughout the galaxy is also being carried out. One of the results of this conversion will be to give a refined version of the preliminary diagram of spiral structure already published (**7**). In co-operation with the Leiden observatory a diagram representing the whole galaxy is also being prepared.

The space density of neutral hydrogen relative to the total density in the galaxy has been examined (**8**). The central region of the galaxy is relatively poor in hydrogen by comparison with the outer parts beyond the Sun's distance. The relative space density of neutral hydrogen near the Sun is 15 per cent; while integration over the whole galaxy yields a ratio of hydrogen to total mass of about 2 per cent.

The 21 cm observations, which provide extensive evidence on the location of the plane of the galaxy, are also being studied in connection with the proposed revision, by the I.A.U., of the system of galactic co-ordinates.

A new multichannel receiver has recently been put into operation. This equipment embodies 30 channels covering a bandwidth of about 1 Mc/s. The number of channels will shortly be increased, extending the total bandwidth to 1·5 Mc/s.

2. *Solar radio waves.*—Daily radio pictures of the Sun are now being obtained from observations with the new 64– aerial crossed interferometer (**2, 4**). This " radio heliograph ", operating at a wavelength of 20 cm, has pencil beams 3′ arc in diameter. The daily pictures delineate individual sources of high emission in the corona above optically active regions. From observations of the displacement of these sources relative to the optical features as the Sun rotates, and particularly from observations at the limb of the Sun, it is inferred that the emitting regions are at heights of about 50 000 km. Investigations of the effects of solar magnetic fields on radio emission are being made by rotating the aerials in one arm of the interferometer to provide polarization information.

Observations of the dynamic spectra of solar bursts are being continued. Considerable extensions have been made to the swept-frequency interferometer with the aim of increasing its accuracy to the point where the " plasma hypothesis " can be directly tested (**32**). Initial results have confirmed that bursts of spectral type III occur close to flares. Sources of bursts of spectral types I and III are of relatively large angular size: the sizes increase with decreasing frequency up to ~ 10′ arc at 40 Mc/s.

The analysis of the relationship between bursts of spectral type III and flares (undertaken in collaboration with the Division of Physics, C.S.I.R.O.) has now been published (**12**). Simultaneous measurements of the polarization and spectrum of bursts have confirmed the dominant circular polarization of type I bursts, but have shown that 50 per cent of type III bursts are also polarized (**10**). Observations have revealed a new spectral type consisting of two short-duration ridges drifting rapidly from *low* to *high* frequencies. The second ridge is an approximate repetition of the first after a delay of 1½–2 sec. A preliminary report on these *reverse drift pairs* was presented at the Boulder meeting of the U.R.S.I. in 1957. It is suggested that the second element may be an echo from the solar corona.

Data from the radio heliograph and radio spectrograph, as well as from single frequency observations of solar emission at 600 and 1400 Mc/s, are contributed to the I.G.Y. reporting network. The Radiophysics Laboratory has been selected as the (parent) World Data Centre C for Solar Radio Emission and Mr S. F. Smerd is editing this section of the Annals of the I.G.Y.

3. *The solar system.*—Attempts were made to observe Comet Arend–Roland at 85 and 19 Mc/s, but at neither frequency could emission or absorption be detected above fairly low limits (**26**).

Few observations have been made of Jupiter noise, owing to concentration on other work, but the anslysis of the previously reported observations was completed (**5**). One interesting feature was that bursts of Jupiter noise did not appear at the same instant at two stations 25 km apart, suggesting some local effect superimposed on the radiation emitted from Jupiter.

4. *Theoretical.*—The statistical effects of blending and imperfect resolution of sources in the beam of a radio telescope have been studied by means of a one-dimensional random " artificial sky " of 5000 sources constructed with an electronic computer.

Studies of electromagnetic heating of the solar chromosphere and corona have continued (**22**). The rates of absorption of hydromagnetic waves in the galaxy have been evaluated, providing evidence against Fermi's cosmic-ray theory, at least in the spiral arms (**19**). Conditions in the Crab nebula have been studied, leading to the conclusion that most of the magnetic field was created well after the explosion, at an average rate corresponding to more than 10^4 times the total output of solar energy (**20**). Mechanisms for the conversion of nuclear to magnetic energy have been suggested.

Theoretical studies have also been made of the ray-paths of whistling atmospherics.

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Perth Observatory

(*Director, Mr H. S. Spigl, Government Astronomer*)

The assistant astronomer, whose appointment was mentioned in the last report has now taken up his duties. Work with the astrographic telescope has been increased, and the Markowitz moon camera has been received and is now being attached. 20 plates were taken of Comet Mrkos, 1957d, and 15 positions communicated through the I.A.U. Searches for Comet 1957f were unsuccessful.

The result of 29 occultation observations were communicated to H.M. Nautical Almanac Office.

Further work on the Transit Circle has been carried out, but it has not yet been possible to commence regular observations.

A Shortt Free pendulum clock has now been installed, and is about to be brought into use in the Western Australia time service.

The Milne Shaw and Lamont Vertical seismograph records were analysed, and the information forwarded to 63 reciprocating stations. Preliminary seismological bulletins and results of microseismic recordings were sent monthly to the I.G.Y. World Data centres, and preliminary reports of strong movements within 5000 km of Perth, were cabled to the U.S. Coast and Geodetic Survey through the American Consulate.

Coordination of the work of the Perth ' moonwatch ' team was undertaken by the Government Astronomer, and observations of the Russian artificial satellites were communicated through the Australian centre in Adelaide. Auroral observations from many parts of the State, and tidal values from Port Hedland have also been communicated to I.G.Y. authorities.

The routine work of time service, provision of tidal and astronomical tables, increased information for press, radio and public, and the evening and afternoon visits by the public to the Observatory, have continued as in previous years.

During the year, visitors to the Observatory included their Excellencies the Governor, Sir Charles and Lady Gairdner, Professor and Mrs B. J. Bok, and Dr A. Hogg of Mt Stromlo Observatory, and Dr I. Epstein of Columbia University.

Geophysical Observatory, Christchurch, N.Z.

(*Superintendent, Dr J. W. Beagley*)

The major part of the Observatory's intensive instrumental construction programme was successfully concluded during the first six months of the year. Further modifications made to the Godley Head Panoramic Ionosonde resulted in improved recordings and the Rarotonga Panoramic Ionosonde constructed by Canterbury College Industrial Development Department was shipped to and installed in the Cook Islands during May. The Australian-built automatic ionosonde—J. 28 type—was re-designed and installed in Campbell Island. The telescope units of the Blackett Intensity Meter—Type M.U.2—were arranged to record incoming cosmic radiation in accordance with C.S.A.G.I. requirements. Progress was made with the construction of a meson telescope which will be installed at Invercargill early in 1958.

Recording at all the vertical sounding ionosphere stations under the Observatory's control—Rarotonga, Godley Head, Campbell Island, Scott Base and Hallett Station (in conjunction with U.S.A.)—has been well maintained.

Although some difficulty was experienced during the winter months in receiving coded data from Scott Base and Hallett Station, when high absorption ionospheric storms caused interference in radio communication, the data received at Christchurch from all stations is very well up to date.

Research work on the structure of the *F* region is proceeding and a study of its heat balance being made. The analysis of night-time ionospheric storm characteristics was completed. Seasonal and diurnal variations were investigated as well as relationships with magnetic storms and variations in electron density distributions derived from reduced records. The work indicates that

winter storms have certain features which are distinct from those of other seasons. Electron distributions for the initial hours of both severe and moderate storms seem to show that electrons near the height of maximum density are affected before those in the lower part of the layer.

An investigation of radio propagation conditions within New Zealand was commenced. This project aims at improving the prediction of Maximum Usable Frequencies for local circuits.

Carter Observatory, Wellington, N.Z.

(*Director, Mr I. L. Thomsen*)

Telescope demonstrations and lectures were given on 38 Friday evenings from February to December. Visits by special parties occurred on seven occasions. The total attendance for the year was 2146.

The Observatory has continued to give assistance to amateur societies whenever required and made the Lecture Room available for meetings. For instructional purposes, 3-inch refracting telescopes were on loan to four secondary schools in New Zealand.

Regular observations of sunspots by projection with a 5-inch refractor have been continued. For short periods, frequent photographs were obtained with the 9-inch telescope but due to recurring mechanical trouble with the camera this project has not been very successful. The lack of an instrument maker at the Observatory is a serious drawback. Spectrohelioscope observations have by no means been as regular as is desirable owing to increasing desk work.

The first I.G.Y. parties from the Scott and Hallett stations in the Antartic returned to New Zealand at the end of the year with good records of the aurora. Campbell Island observers have continued with their auroral work very well, but there was delay in putting the All-Sky Camera into operation due to work in changing the camp site. Invercargill I.G.Y. station in New Zealand has made notable contributions by radar, spectroscopic, photographic and visual observations.

Locally, all auroral work for the New Zealand and Antartic regions is fairly up to date although the I.G.Y. requirements for World Data Centres has not yet been fulfilled. This is due in part to lateness of receipt of clear instructions as well as the general pressure of work. A staff of two looking after the general auroral work is supported under a contract with the Air Force Cambridge Research Centre, U.S.A., without which the task would be impossible.

Much advance has been made in researches on the statistics of aurorae based on the last 25 years' records.

Short-term ionospheric disturbance forecasts were issued to the Post and Telegraph Department, New Zealand Broadcasting Service and the Royal New Zealand Navy.

A moon-camera was received on loan from the U.S. Naval Observatory at the end of the year and had been adapted for use with the 9-inch refractor. Timing arrangements have still to be completed.

Many external lectures have been given at the popular level and information supplied to the press as required. General astronomical information has been provided on application to calendar printers, architects, solicitors, the armed forces and Government Departments.

Canterbury University Observatory, N.Z.

(*Director, Mr K. W. Roth*)

The entire equipment of the Observatory consists solely of a 6-inch refractor for visual observation in equatorial mounting without timepieces. Under these circumstances no serious scientific work has been undertaken, but once a week the public was given an opportunity to look at objects in season through the telescope. The response was good, though not as sensational as at the time of the favourable Mars opposition in 1956. The average attendance was about 25, but occasionally the number of visitors was more than twice as much.

An extension of the Observatory and the scope of its work is planned in conjunction with the erection of a new Science block within the next few years.

Mr M. Abdul Ahad's Observatory, Basrah, Iraq

The main items of equipment at this Observatory, which is the only one in Iraq, are a 2·4-inch refractor, a 2-inch refractor and a 6-inch reflector.

With the 2·4-inch refractor, augmented by further equipment presented by the Kodaikanal Observatory, 96 sketches of sunspots have been made during the year.

A small camera has been attached to the 2-inch refractor and is being used experimentally for solar photography. 73 negatives were exposed, of which 40 of 3-inch diameter were fairly good.

The equatorially mounted 6-inch reflector is used for lunar and planetary observations. 40 observations of the Moon, and 25 of the planets, have been made in the year.

Active contact is maintained with the local public and press, and talks and demonstrations are given, on request, to students and interested members of the public.

Godlee Observatory, College of Science and Technology, Manchester

(*Curators, Manchester Astronomical Society*)

During 1957 the work at Godlee Observatory followed very closely its usual pattern. Thursday evenings were reserved for members of the Manchester Astronomical Society, who attended in fair numbers for observational work. On occasions when the weather was bad, discussions were arranged. The Manchester University Astronomical Society also made good use of the Observatory.

A number of parties from various outside educational organizations and youth clubs spent evenings at the Observatory, and a demand for outside lectures was met by the Wardens.

Routine solar observations were made when weather permitted, but conditions on the whole were not good.

Observations of Comet 1956h were made on a number of nights.

Observations of Jupiter were made in the early part of the year, and a number of photographs were taken of the lunar eclipse on May 13.

Mr J. D. Bestwick's Observatory, Leek, Staffordshire

During 1957 observations of fine lunar clefts and domes were carried out with the 12-inch reflector. Several lunar plates were taken with the telescope and good results were obtained.

Drawings of Mercury, Venus and Jupiter were made, and as in previous years, all observations were sent to the Sections of the British Astronomical Association and to the American Association of Lunar and Planetary Observers.

Over 60 people visited the Observatory.

Dr J. L. Haughton's Observatory, Littleton, Nr Winchester, Hants

Nine lunar occultations were observed during the year, and a number of photographs of Comets Arend–Roland and Mrkos were taken. The Observatory was visited by 42 people.

Mr M. B. B. Heath's Observatory, Kingsteignton, Devon

Physical observations of Mercury and Venus by day and of Saturn by night were made whenever practicable. A number of occultations (disappearances on the dark limb) were observed and timed.

Mr F. M. Holborn's Observatory, Peaslake, Surrey

During 1957 1543 observations were made of 72 variable stars and novae on 126 nights. The totally-eclipsed Moon was photographed at the focus of the 12-inch reflector on May 13. The Sun was observed on 231 days for spot counts and naked-eye spots. All records were, or will be, sent to the British Astronomical Association except those of Gamma Cassiopeiae which were sent to the Norman Lockyer Observatory.

Mr Patrick Moore's Observatory, East Grinstead, Sussex

As in previous years, the main observational work has dealt with the Moon, Venus and Jupiter. The 12·5-inch reflector remains the principal instrument. Lunar work has been concentrated upon the preparation of a catalogue of domes, though as yet this catalogue is nowhere near completion. During 1957 there were many visitors to the Observatory, including many young members of the Junior Astronomical Society.

Mr G. E. Patston's Observatory, Eastbourne, Sussex

Latitude: N 50° 45′ 16″·2
Longitude: E 0° 16′ 4″·5 ($0^h\ 1^m\ 4^s·3$)
Altitude: 45·24 metres (148·42 ft)

Normal work was interrupted on March 23 by sudden illness which closed the Observatory for six months except for sporadic observing. Continuous

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observing was resumed in October on a restricted programme devoted entirely to U Gem- and Z Cam- type stars. Seeing conditions were inferior to those of 1956. Records are communicated to the B.A.A.

The Observatory's coordinates, not previously published, are given above.

Through the courtesy of the new owner of the site the Observatory remains undisturbed.

Dr R. L. Waterfield's Observatory, Ascot

During the year the $f/4{\cdot}5$ Cooke triplet of 26-inch focus continued to be used for cometary photography with blue-sensitive plates. With this instrument 33 good plates were secured of comet Arend–Roland and 7 of comet Mrkos. In addition 30 plates were obtained of the former comet with a smaller camera and a red-sensitive plate-filter combination. Two of the five Arend–Roland plates taken with the Cooke lens before perigee were measured and reduced, and the positions published in the I.A.U. circulars. This comet was last photographed on August 3 when it still had a considerable tail; yet subsequent long exposures in September and October showed no trace of the comet.

Observations of 4 occultations of stars by the Moon were communicated to H.M. Nautical Almanac Office. Towards the end of the year experiments were started in obtaining timed photographic positions of the Russian artificial satellites and during December two successful plates were obtained and measured.

The observations were greatly facilitated by Mr E. A. Whitaker who by permission of the Astronomer Royal spent a week at the Observatory during the apparition of comet Arend–Roland; and by Mr J. W. Siddorn, of the Imperial College of Science and Technology, who has been helping at the Observatory since April.

Dr H. P. Wilkins' Observatory, Bexleyheath, Kent

The $15\frac{1}{4}$-inch reflector has been used by Fellows of the local Group of the International Lunar Society for detailed study of the formations Plato, Gassendi, Aristarchus and the limb regions. Among foreign visitors, Dr James Q. Gant, Chairman of the Washington D.C., U.S.A., Group, stayed for a week during August.

Photographs of the lunar eclipse on May 13th, and of Comet Arend–Roland were secured. A five prism spectroscope, capable of adaption to either the reflector or the $3\frac{1}{2}$-inch refractor, has been used for observations of solar prominences. The refractor has been employed for the instruction of juveniles.

The Observatory was closed during September when the Director was in Italy and Sicily, visiting observatories and studying Etna, then in eruption.

REPORTS ON THE PROGRESS OF ASTRONOMY

THE GALACTIC SYSTEM AS A SPIRAL NEBULA

1. *Introduction.*—The view that the Galaxy might have a spiral structure has been expressed almost since the first discoveries of spiral structure in nebulae. The oldest explicit reference to this seems to be in a paper by Stephen Alexander (**1**). Both he and Proctor (**2**), seventeen years later, tried to find support for their spiral theory and to construct to some extent the galactic spiral from the appearance of the Milky Way as inferred mainly from the observations of the Herschels*. In 1900, and more completely again in 1913, Easton (**3**), apparently quite independently and unaware of these earlier suggestions, made a very careful study of the Milky Way as shown by visual and photographic observations, especially with a view to delineating the course of the possible spiral arms of the Galactic System; he placed the centre of the spiral in the direction of Cygnus.

Later developments have made it clear that this representation can hardly resemble the real structure of the Galaxy, the main cause of its failure and of the failure of all attempts to find spiral-like structure being the strong and uneven absorption near the galactic plane; for there is little doubt that many of the features of the apparent Milky Way structure are determined rather by the distribution of absorbing material than by that of the stars.

The extreme flatness of the Galactic System, as well as the frequency of large groupings of O and B stars, had for a long time been convincing evidence that it belonged to the class of spiral galaxies. It was not until 1951, however, that part of the galactic spiral structure was actually found. This was accomplished by using the luminosity criteria for O and B stars, as developed by Morgan, to determine the location of distant groupings of these stars. The first publication on the subject was an article by Morgan, Sharpless and Osterbrock (**4**) in which it was shown that regions of ionized hydrogen were arranged in long stretches which undoubtedly outlined parts of spiral arms (Fig. 1.).

It was a curious coincidence that at just about the same time systematic measures of the 21-cm line of neutral hydrogen were beginning to be made, and only two years later a much more comprehensive picture of the galactic spiral structure could be derived from these radio observations (**5**, **6**).

The 21-cm observations brought about a revolution in the study of galactic structure. The scattering of optical radiation by small interstellar particles is so strong that in almost all directions in the galactic plane this radiation is effectively stopped in a few kiloparsecs. Although there are some places where, through accidental windows in the absorbing screens, one can observe a few stars in the galactic disk up to distances of the order of 10 kpc, these windows are so rare and so small that, but for the radio measures, it might have always remained a hopeless task to outline the general pattern of the galactic spiral.

Radiation in the range of radio waves passes without hindrance through the interstellar dust. For wave-lengths longer than a few metres absorption by

* In 1940 Dr Rosseland informed one of us about Alexander's and Proctor's articles. He also mentioned the possibility that Lord Rosse himself may have had the idea that the Galactic System had a spiral structure. So far, however, no direct published reference to this by Lord Rosse has been found.

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ionized hydrogen becomes appreciable. With decimetre waves the most distant parts of the Galaxy can be explored. Observations in the decimetre continuum can only give the integrated radiation over the line of sight. The 21-cm line gives discrimination in distance. But although the 21-cm observations give discrimination in distance they cannot by themselves provide actual distances. The distance distribution in a given direction can only be inferred from radial velocities. For this we have to suppose that in each part of the Galactic System the average motion of the gas coincides with the circular velocity at the corresponding distance from the centre. Observations of stellar motions indicate that this condition is probably fulfilled to a fair approximation in the neighbourhood of the Sun. It seems plausible to assume that it holds as well for other parts of the Galactic System. But the possibility of deviations must certainly be kept in mind. The 21-cm observations themselves have given clear evidence of systematic divergence from circular motion in some fairly large regions. Moreover, it is certain that the hypothesis is no longer correct in the nuclear part. Within about 3 kpc from the centre the radio observations show that the large-scale motion of the gas deviates greatly from circular motion. We shall return to this below.

Beside systematic deviations from circular motion there are also the smaller-scale, internal motions. The interstellar gas is largely concentrated in clouds; the clouds have considerable random motions. These must be taken into account when computing the distance distribution of the hydrogen in a given direction from the observed velocity distribution. The difficulty is that the distribution of the random motions is very incompletely known, and that, moreover, it seems to vary from region to region.

2. *Rotation.*—A fundamental thing we must know in order to transform radial velocities into distances is how the circular velocity Θ_c varies with the distance R from the centre; in addition we must know the Sun's distance from the centre. We shall denote the latter by R_0.

Once we know both this distance and the circular velocity near the Sun, the 21-cm observations themselves may be used to derive Θ_c for values of R smaller than R_0. As a simple geometrical consideration shows, the circular velocities are given directly by the cut-off of the line profiles at the side of positive radial velocities for the quadrant between 328° and 58° longitude, and at the side of negative velocities for the quadrant between 238° and 328°, provided the hydrogen is distributed evenly over the disk. Actually, the derivation of Θ_c is complicated by the fact that, because of the spiral structure, the gas is very *un*evenly distributed. A second complication arises from the random motions of the clouds, as well as from *systematic* deviations from circular motion.

The rotational velocity near the Sun and the Sun's distance from the centre may be derived by combining the data just mentioned with the constants A and B of differential galactic rotation. The values of the latter constants, which rest on distances of distant stars, are more uncertain than the velocities derived from the 21-cm measures. This causes an uncertainty of about 10 per cent in the scale of the Galactic System. The distance to the centre can also be determined in a direct manner from the RR Lyrae-type variables concentrated near the centre. In this case the accuracy is limited by the uncertainty in the interstellar absorption and in the absolute magnitude of the variables.

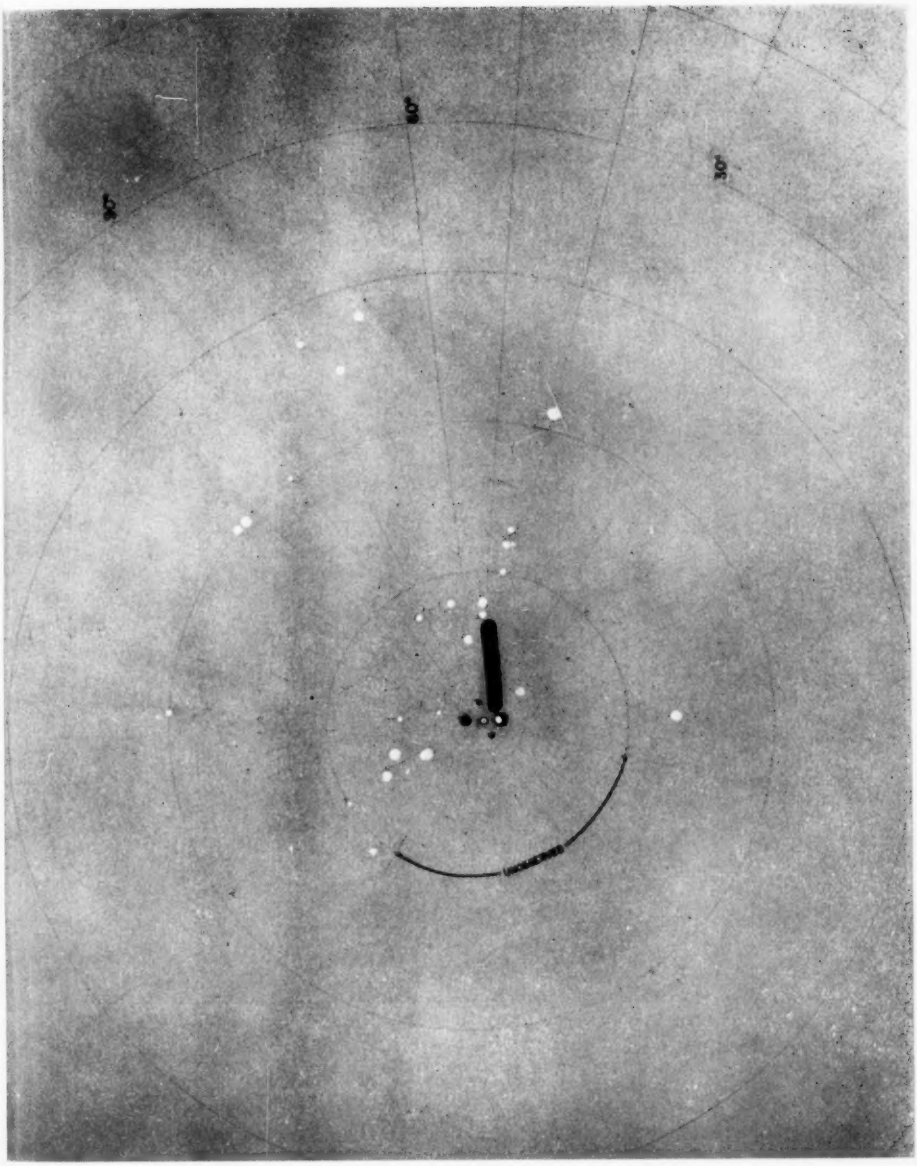

FIG. 1.—*Distribution of emission regions* (**4**). *The numbers indicate galactic longitudes.*
(By courtesy of Dr W. W. Morgan.)

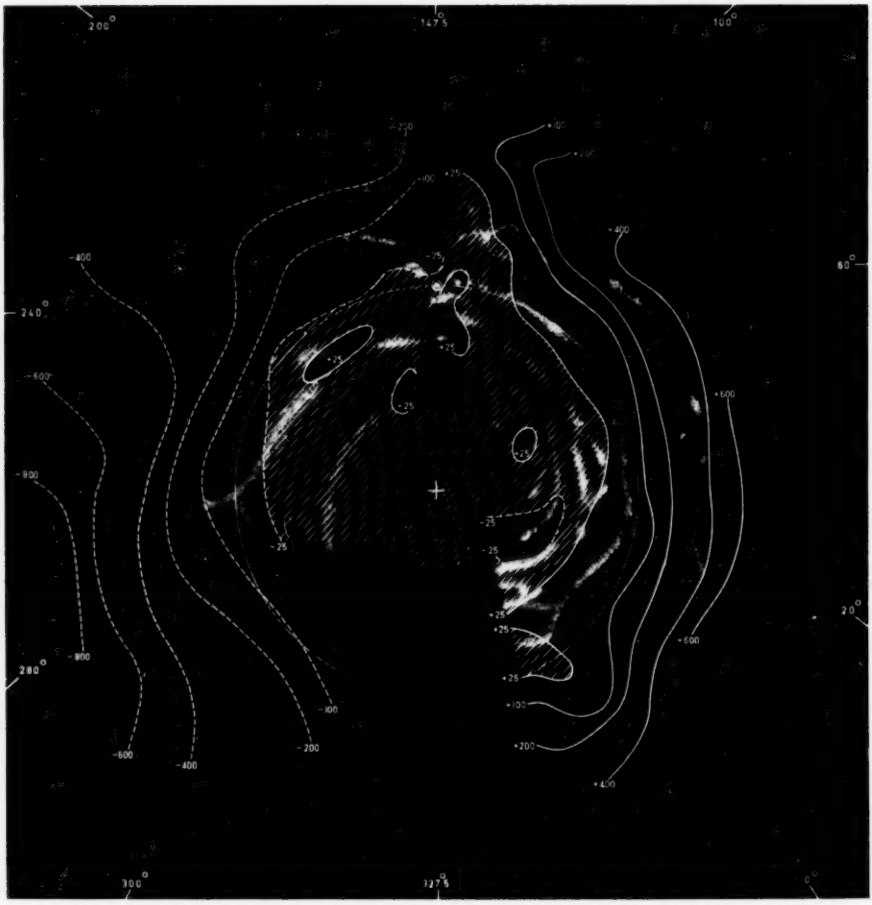

FIG. 3.—*Deviations of the hydrogen layer from an interim solution* (**16**) *for the "principal plane" of the Galaxy* (**6, 9**). *The contour levels are in parsecs. The position of the Sun is denoted by* ○, *the position of the galactic centre by* +.

For the regions situated farther from the centre than the Sun the rotational velocities cannot be determined from radio observations. Here we must rely on values computed from the mass densities in these outer parts, the distribution of mass density being inferred from the star density. For $R > R_0 + 2$ kpc the densities become very uncertain and this affects the calculated rotation curve. The resulting systematic uncertainty in the distances may be 10 per cent.

The rotation curve, as derived by M. Schmidt (**7**) from all available data, is shown in Fig. 2 (full-drawn curve). For the part within $R = 8{\cdot}2$ kpc it is based on 21-cm data discussed by Kwee, Muller and Westerhout (**8**). These referred to the quadrant from 328° to 58° longitude and are shown as dots. Data for the quadrant at the other side of the centre, measured by Kerr and Hindman, are shown as crosses. Taking into account that in the southern longitudes the

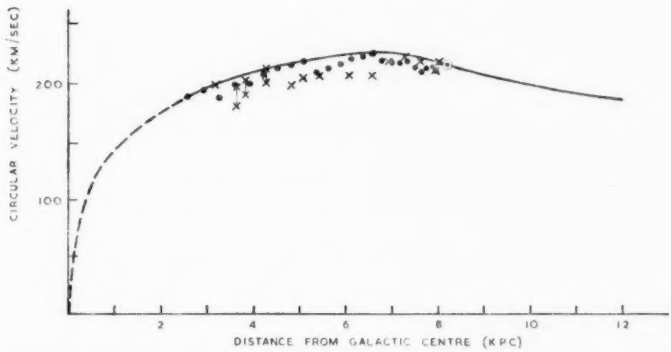

FIG. 2.—*Variation of circular velocity with distance from the galactic centre* (**7, 8**). *Observational points from the northern* (●) *and southern* (×) *sectors have been included, except in the innermost region, where expansion makes the interpretation more difficult.*

line of sight seems to pass more frequently through inter-arm regions at the point where it comes closest to the centre, which causes the cut-off velocities to be smaller than the rotational velocities, the agreement between the two sides of the Galactic System is satisfactory, at least for $R > 3$ kpc. In the innermost region great irregularities occur, which we shall discuss below.

3. *Hydrogen distribution. Spiral structure.*—From profiles of the 21-cm line observed in various directions one can now derive the density distribution of the neutral hydrogen throughout the Galactic System. It appears that most of it is confined to a flat disk. The distance between the surfaces where the density has dropped to half the value in the central plane is about 220 pc, or only about 1/100th of the disk's diameter in the galactic plane. The arms lie for the most part extremely closely in one plane, which we may call the true galactic plane (this makes an angle of roughly 1°·5 with the standard plane as used in the Lund tables). Within a circle of 8 kpc around the centre the points of maximum density nowhere deviate more than 75 pc from the plane, except in a few small areas. Within 6 kpc from the centre the deviations are all less than 30 pc (cf. Fig. 3), or roughly 1/1000th of the diameter of the disk. The extreme neatness with which the gas has arranged itself into such a disk is the more remarkable when contrasted to the unevenness of the distribution *in* the

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plane. For $R > 10$ kpc somewhat greater deviations occur, running up to 600 and 800 pc in the outermost regions of low density. These deviations present a distinctly systematic character, as may be seen from Fig. 3 (cf. also (**9, 16**)).

The hydrogen distribution in the plane of the disk is shown in Fig. 4. The densities are indicated by contour lines and different types of shading. The picture is based partly on results derived in Leiden (from 340° to 220° longitude) and partly on measures made in Sydney (from 220° to 316°). There was a large region of overlap, inside which the observations agreed very well. The radio telescopes used were a 7·5-m Würzburg and a 11-m meridian telescope, respectively. The beam width to half power was $1°{\cdot}8 \times 2°{\cdot}8$ for the Dutch telescope and 1°·5 for the Australian one.

It should be emphasized that the distribution obtained depends considerably on the resolving power and on the particular assumption made regarding to velocity dispersion, temperature of the gas, circularity of the average motion, etc. We believe that the diagram gives the general pattern fairly well, but the densities must be considered very uncertain, in some cases by a factor of two or more. The relatively wide beams efface the detail structure of the interstellar medium and are suitable for observing the large-scale features with which the present report is concerned. The zone between latitudes $-10°$ and $+10°$ was practically completely covered from 318° to 125° longitude; in the remaining longitudes the observations were spaced at somewhat larger intervals, so that roughly half of the surface between $-10°$ and $+10°$ may have been covered.

The distribution of the hydrogen evidently shows great irregularities. Nevertheless, several arms can be followed over considerable lengths. The Sun appears to be situated near the inner edge of an arm which stretches out in the direction of Cygnus and can be followed more or less continuously down to about 340° longitude. The continuation of the arm in longitudes past that of the anticentre is not so well defined; it probably passes through the big Orion association. Because of this the entire arm has been called the Orion arm. In the longitudes from 65° to 130° there is a conspicuous arm at a distance of about 10·5 kpc from the centre. This has been called the Perseus arm, after the large association around h and χ Persei which is situated close to it. The broad, almost circular structure between $R = 9$ and 12 kpc, extending from 65° down to 340°, may be a continuation of this arm. On the southern side there is no counterpart to this prominent outer arm. The pattern ends in a more straggly style. Inside $R = 8$ we meet between $R = 6$ and 7 the "Sagittarius arm"; which appears to move in towards the centre when we follow it in clockwise direction. At longitudes between 200° and 310° the structures may be slightly less continuous. For this reason and because of the great gap between 315° and 340°, where, except at small R, the differential rotation is too small to separate the various arms, it is not yet possible to follow the arms all around the centre.

The outer boundary of the disk appears to be about 15 kpc from the centre, but the average density diminishes very gradually, and it is quite possible that more distant bits will be discovered. Fig. 5, based on the sector between 340° and 220° longitude, indicates how the overall average of the gas density varies with distance from the centre. There is a distinct maximum around $R = 7$ kpc. It may be noted that a similar maximum, around $R = 11$ kpc, occurs in the Andromeda nebula, but there it is much sharper. The distribution in the Andromeda nebula is shown by a dotted line in Fig. 5. The thickness of the

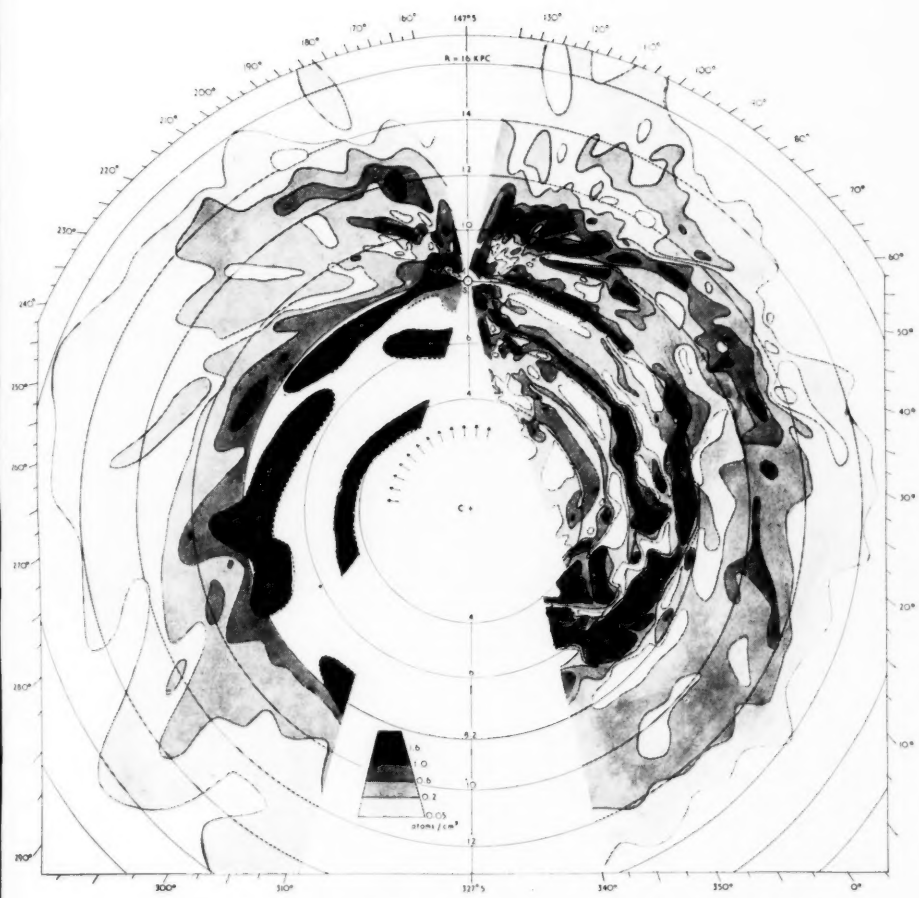

FIG. 4.—*Distribution of neutral hydrogen in the Galactic System. The maximum densities in the z-direction are projected on the galactic plane, and contours are drawn through the points.*

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layer is unknown in this case; the densities have been computed on the hypothesis that it is the same as in the Galactic System.

Because of the imperfections in the observed hydrogen distribution it is still somewhat difficult to assign to the Galactic System an accurate classification among the classes of spirals. Judging from the number of continuous arms cut by a radius vector and from their spacing, it is similar to the Andromeda nebula and M 81, possibly slightly " later ". It would therefore be of class Sb.

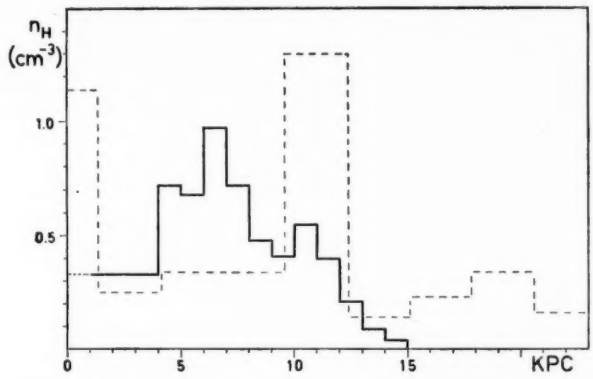

FIG. 5.—*Variation of average density in the galactic plane with distance from the centre* (6), *and comparison with the Andromeda nebula* (17) (*dotted line*).

It is certainly much more compact than typical Sc galaxies like M 101 and M 33, while it does not show the closely wound arms of early Sb nebulae like NGC 4594. Moreover, it clearly has a considerable central bulge of stars, but nothing comparable to that in NGC 4594. An additional indication of its place in the sequence of spiral galaxies may be obtained through a comparison of the fraction of the total mass which exists in the form of interstellar gas. For our Galaxy this is 2 per cent, for the Andromeda nebula it is 0·8 per cent, while in M 33 4 per cent of the mass is interstellar hydrogen. In elliptical galaxies, on the other hand, the interstellar component seems to be quite small. These considerations would make the Galactic System just a little " later " type than M 31.

4. *Expansion in nuclear region.*—In Fig. 4 one conspicuous arm has been drawn in a tentative manner, viz. the arm indicated by small arrows at about $R=3$ kpc. It can be followed from about 303° to 331° longitude. Its distance has been inferred from the fact that it appears to become tangential to the line of sight around 303°. If observed with a sufficiently narrow band and beam it stands out as a well-defined and rather sharp maximum in the line profiles. In Fig. 6 the velocities of this maximum are plotted against longitude. The run is extremely regular. The arm can be seen in absorption against the strong source Sagittarius A, which is presumably situated at the galactic centre*(18). The absorption-line velocity has been indicated by a cross in Fig. 6; it agrees perfectly with the emission velocities in the surrounding points. It shows that the arm passes between the centre and us, and that, in addition to rotation, the

* This may be a concentration of ionized gas of about 200 000 solar masses, of the same nature as the concentrated masses of gas which are so frequently observed at the centres of elliptical galaxies; generally the latter masses are somewhat higher.

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gas of the arm has a velocity of 53 km/sec away from the centre. We shall therefore refer to it as the " 3-kpc expanding arm ". It is certainly not the only feature of this kind. From the line profiles in directions differing less than about 15° from 327°·7 one can see that in the part within 2 or 3 kpc from the centre large systematic deviations from circular motion must be the rule rather than the exception. Deviations up to 200 km/sec have been found. They are not of the nature of random motions, but represent mass motions of extended concentrations of matter. In the case discussed above we are clearly dealing with an *arm*. It is still unknown whether the other moving features are likewise

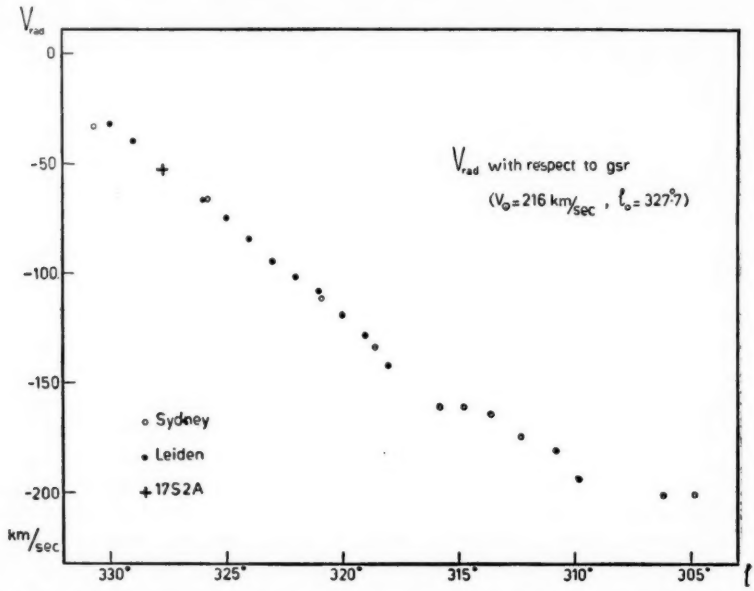

FIG. 6.—*Variation with longitude of the radial velocity of the " 3-kpc expanding arm ". The observed values were corrected for the motion of the Sun around the galactic centre. The Leiden points were measured with the Dwingeloo 25-m telescope. (Courtesy of Mr G. W. Rougoor.) The Sydney points were measured with the Sydney 11-m meridian telescope. Further details concerning the expanding arm are given in* (10).

arranged in arms or whether they are just loose bits. It is plausible to assume that, as in the 3-kpc expanding arm, the gas in these other " arms " is streaming away from the centre. Indeed, recent absorption measures in Sgr A by Rougoor show that the gas clouds for which the radial velocity (corrected for solar motion) exceeds 30 km/sec *all* move away from the centre. He has been able to verify this for radial motions between about 30 and 140 km/sec. It is worth remarking that these expanding velocities must be almost exactly in the galactic plane, as practically all of these features lie within 100 pc of the true galactic plane.

Clearly, estimates of the circular velocity in the nuclear parts are rendered very doubtful by the existence of these large deviations from circular motions, in particular because they appear to have the character of systematic velocities away from the centre. For this reason the rotation curve of Fig. 2 is quite uncertain in the part within $R=3$.

It is possible that outward motions of smaller amount occur also at larger distances from the centre. In principle this could be investigated by special 21-cm line observations. At the time of writing these had not yet been made.

The gas motions in the central part may be strongly influenced by large-scale magnetic fields (cf. Section 5). It is unknown to what extent magnetic forces affect the motions beyond 3 kpc. But it is well to keep in mind the possibility that these may have caused appreciable errors in the gravitational forces and the mass distribution computed from the observed rotation up to about $R=5$ kpc. However, there is good reason to believe that at distances R comparable to that of the Sun such effects are practically negligible. For, in the general vicinity of the Sun, the average motion of stars that are old enough to have become practically independent of the gas from which they originated, is nearly the same as the motion of the gas. There may be a difference of about 5 km/sec between the solar motion with respect to A stars and that with respect to the gas and the very young stars, but such an amount is of no consequence in comparison with the total velocity of rotation.

5. *Evolution of spiral structure.*—What new information can the observations of the spiral structure of the Galactic System give us which could not be obtained from external galaxies, and what hope do they hold out for getting an insight into the processes causing spiral structure and maintaining it after it has originated ? The information may be classed in three categories:

(*a*) The gaseous nature of spiral structure.

(*b*) Relation with the distribution of *stars*.

(*c*) The field of force.

We shall briefly consider each of these subjects.

(*a*) Although convincing evidence that interstellar gas is concentrated in the spiral arms had been obtained previously, in particular in Baade's surveys of emission nebulae in M 31 and M 81, the 21-cm observations of our own galaxy furnish for the first time quantitative data on the concentration of gas in the arms. Although the evidence requires further substantiation, it is already clear that in many inter-arm regions the density is small compared to that in the arms.

A datum of extreme importance for the understanding of the phenomenon of spiral structure is the amount of random motion in the interstellar medium. On this point very little information can be gathered from other galaxies. For our own galaxy the large new radio telescopes will presumably enable us to collect a considerable amount of data on random velocities.

The astounding flatness of the System, which has been commented upon above, is of importance in connection with the internal motions in the medium. Not only does it provide a measure for the average random motion of the interstellar clouds, but it also indicates that there must have been a very large amount of exchange of momentum from the innermost to the outermost parts of the disk.

A fundamental question in the problem of spiral structure is whether this is essentially a phenomenon of *gas* dynamics (possibly connected with magnetic fields) or whether the stars themselves make the major contribution to the density of the arms, so that the problem would be one of *stellar* dynamics. The latter possibility has been worked out in considerable detail by Lindblad (**11**). Some phenomena in external galaxies give strong indications that the spiral formation

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is intimately related to their content of interstellar gas, and that the presence of enough gas is an essential condition for the existence of spiral structure (**12**). But it would evidently be very important to know whether in the Galactic System the arms consist mainly of gas or of stars.

(*b*) It is clear that stars which have recently been formed from the gas must be situated in the gaseous arms. The connection between young stars and the general distribution of the gas is demonstrated in the surveys of OB associations (**13**) and δ Cephei variables (**14**). Surveys of such supergiants, fragmentary though they are because of interstellar absorption, are extremely valuable for the investigation of the spiral structure. They can bridge gaps in regions where the differential rotation is too small to resolve the 21-cm radiation and, because the stellar distances are known, they can give information on systematic deviations of spiral arms from circular motion.

It may be estimated that stars will in general stay within the spiral arms in which they were born for several hundred million years, but that after about five hundred million years they may show appreciable differences from the distribution of the gas if the latter is supposed to be kept in its spiral pattern by other forces in addition to that of gravitation. So far, no sufficient evidence for a decisive comparison between the distribution of older stars and gas has been obtained.

(*c*) In no other galaxy are the velocities of rotation and the gravitational field known with an accuracy comparable to that obtained in the Galactic System. Though the arms cannot yet be followed around the whole system, it is fairly clear from the parts over which they can be followed that the arms are trailing. If we suppose that like other regular Sb spirals the Galactic System has two main arms, the spacing between the large arms gives an indication of their average inclination. The observed differential rotation gives us then at once the time scale in which the present spiral structure would radically change its appearance. This scale is found to be between 100 and 200 million years. This is so short compared to the age of our galaxy that we are forced to conclude that the arms must either smooth out rapidly and then be replaced by completely new ones, or that there is some mechanism that keeps up the existing arms, notwithstanding the stretching effect of the differential rotation. A possible mechanism is that of gas transport between neighbouring arms. Rough estimates indicate that this would work in the right direction and might be of the right order. But such a mechanism, though it might preserve the arms once they are formed, would give no clue to the way in which the spiral structure could have originated, nor how the expanding arms in the nuclear region come into existence. The latter problem is acute, because, considering the speed with which they move out, these expanding features must be formed at relatively short intervals.

Though it is still entirely obscure how magnetic fields could produce these phenomena, it is tempting to think that there is some connection between large-scale interstellar magnetic fields and spiral arms. Three phenomena point in this direction. The first is that interstellar polarization of light indicates the presence of magnetic fields which, at least in some cases, seem to have their average direction along arms. The second is concerned with the continuous radio-frequency radiation. Part of this is strongly concentrated to the galactic plane. Its intensity distribution in the plane appears to be clearly connected

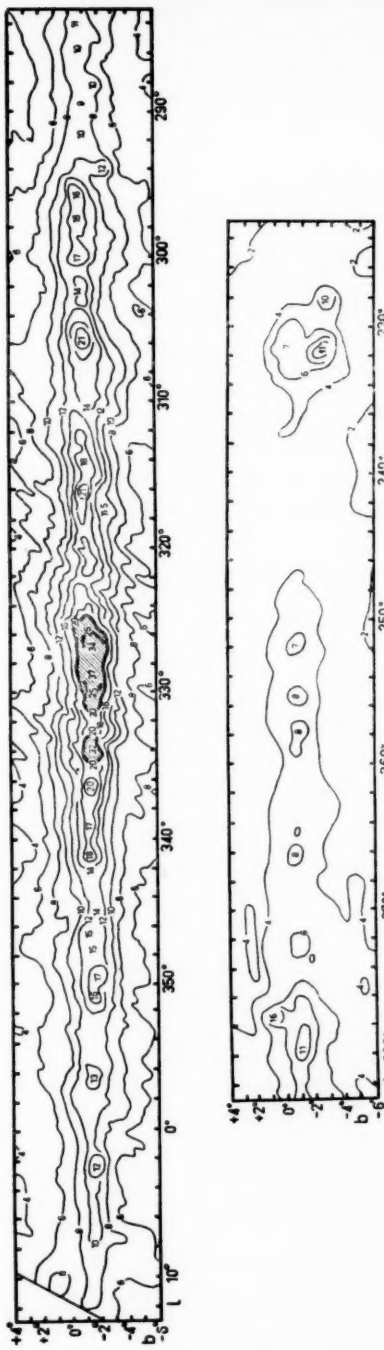

FIG. 7.—*Distribution of brightness temperature near the galactic plane at 3½ m wave-length* (**15**). *The unit is* 1000 °K. (*By courtesy of Dr B. Y. Mills.*)

with the spiral structure. This is well brought out by Fig. 7, which gives the continuous radiation at 3·5 m wave-length observed by Mills, Hill and Slee (**15**). Practically all of the radiation at this wave-length, even at low latitudes, must be of non-thermal origin. This was shown by a comparison with a survey at 22 cm wave-length by Westerhout (**18**). This non-thermal component may be largely "synchrotron" radiation from high-energy electrons moving in interstellar magnetic fields. If this is correct, Fig. 7 indicates that the interstellar fields may be strongly concentrated in the arms.

The third phenomenon relevant in this connection is the radio corona of the Galactic System. We shall not deal with this in the present report, except to mention that its existence around the Galactic System as well as around the Andromeda nebula gives considerable support to the idea that magnetic fields are an essential factor in the large-scale structure of spiral nebulae. It should also be pointed out that the corona is likely to be the reservoir replenishing the central region with the gas needed to keep up the fast stream moving out of it into the larger disk.

It is clear that as yet we have made little or no progress towards an understanding of the origin of spiral structure. But the recent investigations on this structure in the Galactic System indicate at least some new roads for future research into this problem.

J. H. OORT.
F. T. KERR.
G. WESTERHOUT.

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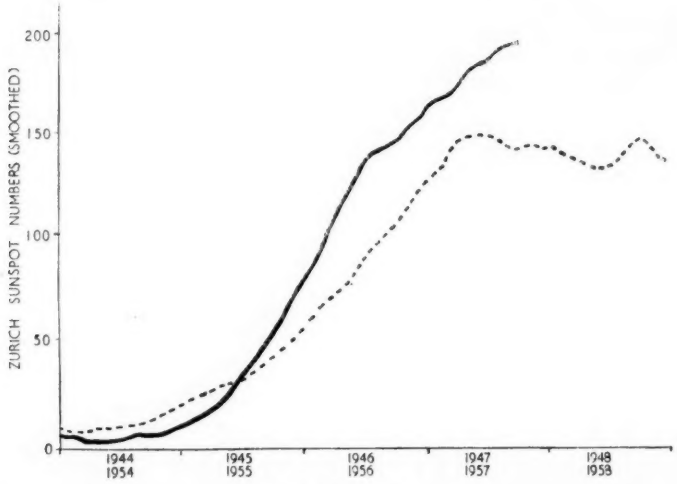
SOLAR ACTIVITY

Sunspots.—Following the extremely steep rise from minimum phase to a peak in 1956 November, solar activity slackened somewhat during the early part of 1957. By June, however, intense activity was renewed and, after another temporary decline, the level rose towards the end of the year to an unprecedented height; this period may well prove to be the maximum of the present cycle.

The Zurich relative sunspot number for October was 253·8, a figure much in excess of any since reliable observations began. In previous cycles the highest mean daily sunspot number for any year was 152, the value for 1947. The number for 1957 was 190.

Sixty-one sunspot groups with maximum areas exceeding 500 millionths of the hemisphere were observed during the year, while the total number of groups recorded at the Royal Greenwich Observatory can be provisionally put at not many short of 800, or a third more than in 1956.



A feature of this maximum is the high incidence of small and medium sized sunspots, although no group of outstanding importance has yet been observed.

The continued appearance of high latitude spots ($\geqslant 40°$) is another unusual feature. In previous years of sunspot maximum, spots in these latitudes have only amounted to some 1 per cent of the total. In 1957, however, the figure is about 3 per cent.

On 1957 June 21 a group of 50 millionths in area appeared in latitude 50°·3 N. It had grown by the next day but then passed round the limb. This appears to be the highest latitude group (other than pores of an ephemeral nature) recorded in the Greenwich series.

September proved the most active month for solar flares, sudden enhancements of atmospherics, magnetic storms and cosmic radiation effects, most of these aspects of solar activity being on a greater scale than in any previous period.

The diagram shows the progress of activity since 1954 represented by Zurich sunspot numbers (smoothed), compared with that of the previous sunspot

cycle. The years 1944–48 are represented by a broken line and 1954–57 by a continuous line. P. S. LAURIE.

Prominences.—During 1957 prominence activity continued to be high, although there was a slight decrease compared to 1956. The mean daily areas and numbers of calcium prominences at the limb as derived from photographs obtained at Kodaikanal were as follows:

	Area in square minutes					Number				
1957	North	South	East	West	Total	North	South	East	West	Total
Jan.–June	2·72	2·32	2·48	2·56	5·04	4·91	4·19	4·36	4·74	9·10
July–Dec.	3·22	2·06	2·24	3·04	5·28	4·68	3·68	3·77	4·59	8·36
Whole year (weighted mean)	2·92	2·23	2·39	2·76	5·15	4·82	4·00	4·13	4·69	8·82

This shows that, since 1956, prominence activity as represented by areas and numbers had slightly decreased, the decrease in area being 13 per cent. and that in numbers 7 per cent.

The distribution of areas in the northern hemisphere, in five-degree ranges of latitude, showed two peaks of activity in the zones 35°–40° and 60°–65°, with a secondary maximum at 10°–15°. In the southern hemisphere the maximum activity was at 35°–45°. The activity in the southern hemisphere continued to be less than in the northern hemisphere. The eastern preponderance in prominence area observed last year had changed into a western preponderance during 1957.

Doppler displacements of the H-alpha line in prominences and absorption markings observed with the prominence spectroscope and the spectrohelioscope are summarised below:

	North	South	East	West	To red	To violet	Both ways	Total
Prominences	119	101	110	110	—	—	220	220
Dark markings	7	14	9	12	—	1	20	21

The heights of 47 fairly tall prominences were measured in H-alpha, D_3 and H-beta lines with the prominence spectroscope. These were compared with the corresponding heights in the K line as obtained from the spectroheliograms. The average heights were:

K	H-alpha	D_3	H-beta
85″·1	71″·4	56″ 1	49″·6

12 instances of sudden disappearances of disk absorption markings and limb prominences were observed during the year.

The mean daily areas and numbers of hydrogen absorption markings on the disk as obtained from Kodaikanal records are given in the following table :

	Area in millionths of the Sun's visible hemisphere (uncorrected for foreshortening)					Number				
1957	North	South	East	West	Total	North	South	East	West	Total
Jan.–June	2567	2558	2368	2757	5125	13·77	13·59	13·04	14·32	27·36
July–Dec.	2577	2334	2237	2674	4911	15·50	13·96	13·91	15·55	29·46
Whole year (weighted mean)	2572	2469	2316	2725	5041	14·49	13·75	13·41	14·83	28·24

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Compared with the previous year, the activity as judged by areas showed a slight increase of 3 per cent while the numbers showed a decrease of 6 per cent. The peaks of activity, according to the areas, in both the hemispheres were at 35°–40°. The activity, as judged both by areas and numbers of absorption markings, was less in the southern hemisphere. The western preponderance in area shown by limb prominences is also evident from the area of absorption markings.

A. K. DAS.

COMETS (1957)

In 1957, thirteen comets were under observation, two of them being naked-eye objects which attracted much attention. This report includes notes on six comets discovered in previous years, three periodic comets whose returns had been predicted, two new comets, and the two comets whose orbits of small eccentricity allow them to be seen every year.

The appearance of a bright comet always causes intense activity in the world's observatories, but observations of the fainter periodic comets are all too few, and records of their recovery and observation owe much to the untiring efforts of Dr Elizabeth Roemer, who now works at the Flagstaff station of the U.S. Naval Observatory. There she is able to make use of the 40-inch reflector, which is of the Ritchey-Chrétien type and operates at $f/6{\cdot}8$. The plates normally used are 4 by 5 inches, covering a field of about 40′ by 50′. On the photoelectric magnitude sequences in selected areas the limiting magnitude is about 20·9 on a 30-min exposure on unfiltered 103a–O plates. Magnitudes are normally determined by comparing the image of the comet on exposures of about one magnitude above the plate threshold with similarly exposed plates of stars in the selected areas. The resulting values are several magnitudes fainter than visual determinations, and the differences grow larger as the comet becomes more diffuse. Miss Roemer comments that the method gives results similar to those obtained by Jeffers at Lick and by Cunningham at Mt Wilson, and to the photographic magnitudes determined by Van Biesbroeck with the 82-inch reflector at McDonald. Magnitudes from the 24-inch at Yerkes are brighter on the average by about one magnitude, and small telescopes can easily give magnitudes brighter by 5 to 6 magnitudes without indicating any physical difference in the comet.

These comments are interesting in explaining the discrepancies between individual estimates of the brightness of comets, but much remains to be done to obtain some uniform method of measurement. Smyth reports from Dunsink that some experiments on photoelectric measurement through a varying diaphragm equivalent to one minute of arc at unit distance (Merton, *I.A.U. Trans.*, **8**, 205, 1952) gave homogeneous light curves, and this method appears worthy of further study.

Comet Schwassmann–Wachmann (1) was photographed at Flagstaff on a number of occasions from July 21 to December 11 and a paper is in press giving details of these observations. There appear to have been further outbursts of light during the year, one on August 30 being suspected from the appearance of the comet on the following day, while a second on October 13 was actually recorded on a series of plates taken by Goetz with the Schmidt camera at Sonneberg; the greatest brightness (magnitude 12·5) was recorded on October 15. The comet must thus have increased in brightness by several magnitudes in a few days. Photographs were also taken at Lick on August 21 and September 24.

Comet Oterma was photographed at Lick on December 3, and showed a nearly stellar head of magnitude 17 with a thin tail 1′ long in p.a. 290°.

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1954 h, Baade, was photographed at Lick on February 19, when it had an almost stellar nucleus in a coma of 20″ diameter, magnitude 16·5. It was also recorded at Flagstaff in September and November. At Lick on November 2, a 90-minute exposure showed a somewhat diffuse object of magnitude 19·5, and the last record at Flagstaff on November 26, with the comet in declination −37° at low altitude, describes it in similar terms.
(*Observations* 1954 *July* 31 *to* 1957 *November* 26)

1954 k, Haro-Chavira, was recorded by Van Biesbroeck eight times between March 21 and July 24, when the magnitude had been reduced to about 17, fainter than expected. Miss Roemer recorded the comet in June and July, but estimated the magnitude on July 21 as 19·3. There was then a nearly stellar nucleus, with a fan-shaped tail 0′·4 long in p.a. 200°. The comet was recorded again in August (magnitude 18, Lick) and September (magnitude 19, Lick, Flagstaff); it was recovered at Flagstaff on 1958 February 7 after conjunction with the Sun.
(*Observations* 1954 *December* 17 *to* 1958 *February, continuing*)

1955 c, periodic comet Ashbrook–Jackson, was photographed at Lick on February 19 as a nearly stellar object of magnitude 18·6.
(*Observations* 1955 *April* 24 *to* 1957 *February* 19)

1956 c, Wirtanen, was photographed on many occasions in the period April to September at Lick, McDonald and Flagstaff. The double nucleus previously reported was again visible, the separation of the two nuclei being about 8″·5. At the beginning of this period the comet must have been about four magnitudes brighter than predicted, and this unexpected increase in brightness was responsible for an I.A.U. telegram announcing the discovery of a new comet. The total magnitude in May and June was about 10 (Lick) and the two nuclei differed in brightness by 2 to 3 magnitudes. A faint tail 2′ long in p.a. 250° (Lick, Flagstaff) was detected in June and July. The comet was also under observation at Cordoba in August and was photographed (Flagstaff, Yerkes) in the new year.
(*Observations* 1956 *March* 16 *to* 1958 *February, continuing*)

1956 h, Arend-Roland, had its perihelion passage on 1957 April 8, and in April and May became a bright naked-eye object. A detailed report on the behaviour of the comet during this period has already been given (*Observatory*, **77**, 128, 1957). The main points of interest were the anomalous tail or spike which projected from the head of the comet towards the Sun, and which extended on April 24 for at least 7°; and the unusual intensity of the spectral sodium lines. Physical observations of this comet were made at many observatories where spectrographic, polarization and photometric measurements were possible.

Beyer (Hamburg-Bergedorf) obtained a fine series of magnitude estimates from January 6 to September 30; it appears that the total magnitude of the comet showed minor variations of about half a magnitude, but no correlation with solar activity could be found. The luminosity law deduced by Beyer would suggest a fourth power law of the heliocentric distance as shown by the formula

$$m = 5{\cdot}15 + 10{\cdot}87 \log r + 5 \log \Delta.$$

The comet was followed by Van Biesbroeck until August 25 (McDonald), when the magnitude was 16; at Flagstaff on November 30 and at Lick on December 3 the image was almost stellar, and of magnitude about 18. The comet was still under observation in 1958 January.
(*Observations* 1956 *November* 8 *to* 1958 *January, continuing*)

1956 i, periodic comet Grigg–Skjellerup, was photographed by Van Biesbroeck on January 2 and was also measured on a 48-inch Schmidt plate taken at Mt Palomar on the same date. Observations were also made at Johannesburg and Tokyo.
(*Observations* 1956 *December* 29 *to* 1957 *January* 7)

1957 a was announced as the recovery of periodic comet Kopff by Van Biesbroeck. Subsequent searches failed to confirm this observation, and it appears that a faint minor planet must have been near the position predicted by Kepinski. It is unfortunate that this comet has not been recovered, since Kepinski's predicted elements indicate that a close approach to Jupiter (0·17 unit) in 1954 caused a severe change in the orbit.

1957 b was announced as a discovery by Rijves of Tartu but was not confirmed

1957 c was periodic comet Encke, recovered on a pair of plates taken with the Crossley reflector at Lick on July 25 with exposures of 34 and 46 mins. The magnitude was then about 18 and the comet showed a centrally condensed coma of about 10″ diameter. On July 31 a sharp nucleus was photographed on a 30-min exposure, with coma about 15″ diam. By the end of August the comet was a diffuse object of magnitude 16·5 and diameter 1′, showing only weak central condensation. It was followed at Flagstaff until September 19, when it appeared visually in the 40-inch reflector as a bright fuzzy patch without nucleus or any marked central condensation. Van Biesbroeck followed it until October 5, when the total magnitude reached 6·3. The comet was not found during a search at Heidelberg on October 8 using the comet finder. Wenzel concludes that the comet was then not brighter than magnitude 6·5.
(*Observations* 1957 *July* 25 *to October* 5)

1957 d, Mrkos, was found on August 2 by naked-eye observation by Antonin Mrkos when measuring night-sky glow at his observatory on Lomnický Stít. At the time of discovery only the tail of the comet was visible, but before daybreak the head could also be seen near the horizon. As is usually the case with a bright comet, a number of independent discoveries were announced, although much delayed in publication. It has been decided to retain the name Mrkos for this comet, although credit for its discovery is also due to (among others) S. Kuragano (Yokohama, July 29) Peter Cherbak (American Airlines, July 31) and Clive Hare (Tamworth, England, August 3).

This was the second naked-eye comet of the year, and was well observed in the evening sky in August. In the early stages there were two distinct tails, the brighter one being curved and showing much fine structure on long exposures. By August 21 (Waterfield) the original curved tail had faded, while the straight tail had become brighter and showed knots of material in rapid motion. The comet faded from naked eye visibility by the end of September, but was followed

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Elements of

Ref.	Comet	T(U.T.)	q	e
(1)	1930 VI P/Schwassmann–Wachmann (3)	1930 June 14·1956*E*	1·011426	0·672673
(2)	1933 III P/Giacobini–Zinner	1933 July 15·1466	0·999516	0·716002
(2)	1940 I P/Giacobini–Zinner	1940 Feb. 17·2017	0·995613	0·716661
(3)	1950 III P/Oterma	1950 July 16·8110*E*	3·404794	0·142745
(4)	1951 I Minkowski	1951 Jan. 15·0401	2·572433	1·001304
(5)	1951 VI P/Pons–Winnecke	1951 Sept. 8·5985	1·160474	0·654594
(6)	1951 VII P/Kopff	1951 Oct. 20·3975	1·494908	0·556224
(7)	1952 II P/Harrington (1)	1952 Feb. 6·6834	1·599111	0·540714
(8)	1953 VI P/Harrington (2)	1953 Sept. 22·1260*E*	1·694011	0·535980
(9)	1956 h Arend–Roland	1957 Apr. 8·0312	0·316062	1·000230
(10)	1957 d Mrkos	1957 Aug. 1·4320*E*	0·35511	1·0
(11)	1957 c P/Encke	1957 Oct. 19·845*p*	0·338123	0·847399
(12)	1957 f Latyshev–Wild–Burnham	1957 Dec. 5·1293	0·53913	1·0
(13)	1957 e P/Reinmuth (1)	1958 Mar. 25·010*p*	2·026247	0·478205
(14)	1957 g P/Harrington (1)	1958 Aug. 11·711*p*	1·605457	0·539673
Predicted elements:				
(1)	P/Schwassmann–Wachmann (3)	1957 Oct. 12·145*p*	1·085613	0·656222
(5)	P/Pons–Winnecke	1957 Dec. 5·499*p*	1·226831	0·640071
(15)	P/Harrington–Wilson	1958 Mar. 21·19*p*	1·665267	0·516050
(16)	P/du Toit–Neujmin–Delporte	1958 Aug. 8·206*p*	1·488309	0·544759
(17)	P/Wolf (1)	1959 Mar. 21·824*p*	2·506895	0·394754

References and Notes to Table of Elements

(1) P/Schwassmann–Wachmann (3). D. A. Kalnin, *UAIC* 1592. Definitive. Prediction for 1957 made from the 1930 elements using Encke's and Cowell's methods over 5 revolutions, with perturbations Mercury to Saturn.

(2) P/Giacobini–Zinner. U. V. Evdokimov, *MS.* Perturbations 1933 to 1940 by five major planets.

(3) P/Oterma. Miss L. Oterma, *Ann. Univ. Turku*, A, 27, 1957.

(4) 1951 I, Minkowski. G. Stănilă, *UAIC* 1617. From 140 observations 1950 May 29 to 1951 December 6, with perturbations Venus to Saturn.

(5) P/Pons–Winnecke. L. Y. Ananjeva, *MS.* From elements 1945–1951 corrected for 1951 observations; prediction for 1957 using perturbations Jupiter and Saturn only.

(6) P/Kopff. F. Kepinski, *Acta Astr.* **7**, part 4, 1957.

(7) P/Harrington (1). W. Wisniewski, *UAIC* 1603. From 29 observations 1951 October 8 to 1952 April 24.

(8) P/Harrington (2). B. G. Marsden, *MS.* From 22 observations in 4 normals 1953 August 15 to December 10.

(9) 1956 h, Arend–Roland. I. Hasegawa, *UAIC* 1619. From 116 observations in 7 normals 1956 November 18 to 1957 June 28.

Cometary Orbits

Period (years)	ω	Ω	i	Equinox	Epoch of Osculation	Ref.
	°	°	°			
5·43	192·3276	77·0524	17·4039	1950·0	1930 June 10·0 E.T.	(1)
6·60	171·7714	196·0045	30·6860	1933·0	1933 July 27·0 U.T.	(2)
6·59	171·7910	196·2499	30·7413	1950·0	1939 Oct. 14·0 U.T.	(2)
7·92	354·8445	155·1317	3·9883	1950·0	1950 Feb. 19·0 E.T.	(3)
...	192·4596	38·1822	144·1505	1950·0	1951 Jan. 14·0 U.T.	(4)
6·16	170·1897	94·4022	21·6901	1950·0	1951 Oct. 1·0 U.T.	(5)
6·18	31·7353	253·0186	7·2202	1950·0	1952 Mar. 9·0 U.T.	(6)
6·50	186·9059	254·2770	18·4940	1950·0	1952 Jan. 16·0 U.T.	(7)
6·98	219·3599	136·6222	11·6011	1950·0	1953 Oct. 30·0 E.T.	(8)
...	308·7808	215·1591	119·9495	1950·0	...	(9)
...	40·274	67·651	93·816	1957·0	...	(10)
3·30	185·2276	334·7290	12·3748	1950·0	1957 Aug. 30·0 U.T.	(11)
...	277·622	210·282	156·720	1957·0	...	(12)
7·65	12·9311	123·5562	8·3986	1950·0	1958 Mar. 18·0 U.T.	(13)
6·51	187·0225	254·3389	18·4708	1957·0	1957 Sept. 26·0 U.T.	(14)
5·46	193·7005	76·6451	17·0810	1950·0	1956 Nov. 3·0 E.T.	(1)
6·29	171·9192	92·9371	22·3288	1950·0	1957 Nov. 18·0 U.T.	(5)
6·38	343·1362	127·7735	16·3794	1950·0	...	(15)
5·91	92·1678	208·9903	2·8688	1950·0	1958 July 16·0 U.T.	(16)
8·43	161·0780	203·9045	27·2975	1950·0	1959 Mar. 13·0 U.T.	(17)

(10) 1957 d, Mrkos. M. P. Candy, *UAIC* 1615. From 19 observations in 3 normals August 4·0, 8·0, 12·0. A residual of 11″ remains in the middle declination.

(11) P/Encke. S. G. Makower, *UAIC* 1595 and *Astr. Circ. USSR* 179. Predicted elements based on 5 apparitions 1937 to 1954 with perturbations Mercury to Saturn.

(12) 1957 f Latyshev–Wild–Burnham. M. P. Candy, *UAIC* 1633. Based on two accurate observations and all available approximate observations October 2 to 25.

(13) P/Reinmuth (1). M. Sumner, *B.A.A. Handbook* 1958. Perturbations by Jupiter and Saturn applied to Cripps's elements in *B.A.A. Handbook* 1950. $\Delta T = +0{\cdot}75$ days.

(14) P/Harrington (1). J. Kordylewski, *UAIC* 1608. Predicted elements using Wisniewski's orbit, first-order pertubations by Jupiter only.

(15) P/Harrington–Wilson. B. O. Wheel, B. G. Marsden, W. H. Julian, *UAIC* 1637. Correction of predicted elements in *B.A.A. Handbook* 1958. Perturbations by Jupiter and Saturn applied to Cunningham's elements *UAIC* 1349.

(16) P/du Toit–Neujmin–Delporte. A. S. Sotchilina, *UAIC* 1628. Based on Boeva's elements 1941, with perturbations Venus to Saturn by Cowell's method. A close approach (0·656 a.u.) to Jupiter caused considerable changes in the elements.

(17) P/Wolf (1). M. Kamienski, *Acta Astr.* **7**, part 1, 1957.

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by Van Biesbroeck until October 5, when the total magnitude was estimated at 7. The last reported observation before conjunction with the Sun was on October 11 (Cordoba), but the comet was recovered in 1958 February (Flagstaff).

Beyer made a series of magnitude observations August 10–October 1, and deduced a second-power law: $m = 3{\cdot}63 + 5{\cdot}51 \log r + 5 \log \Delta$. The comet was of magnitude 2·15 on the night of August 10, with a nucleus magnitude 6·0.

Spectroscopic, photometric and polarization measurements have been reported from many observatories in Belgium, Czechoslovakia, France, Germany, the U.S.A. and the U.S.S.R. Strayjis (Tartu) calls attention to the resemblance of the light curve of this comet with that of the sunspot number curve during the same period, and considers that the appearance of the second tail in August might be connected with intense solar activity on the side of the Sun facing the comet.

(*Observations* 1957 *July* 29 *to end of year, continuing*)

1957 e, periodic comet Reinmuth (1) was recovered by Miss Roemer at Flagstaff on September 20 with the 40-inch reflector. Exposures of 40 min and 60 min showed an almost stellar image of magnitude 20. The comet was photographed again in November (Lick, Flagstaff) and December (Yerkes), by which time it had reached magnitude 17. Perihelion passage is in 1958 March, and the comet is still under observation.

(*Observations* 1957 *September* 20 *to end of year, continuing*)

1957 f, Latyshev–Wild–Burnham, was discovered on October 16 by Latyshev at Ashkabad, using 7×50 binoculars while observing the short-period variable X Arietis; the comet was described as a diffuse eighth magnitude object without central condensation. Independent discovery of this comet was made by Paul Wild of Berne Astronomical Institute and by Robert Burnham Jr., an amateur astronomer of Prescott, Arizona. The comet moved rapidly south and few observations were made, the only accurate ones being those of Giclas (Lowell) and Wenzel (Heidelberg). Prediscovery positions have been found on Sonneberg Sky Patrol plates dated October 2, 3 and 5. The last observation appears to be that of Giclas on October 25; searches at Flagstaff, Johannesburg and McDonald in 1958 January failed to locate the comet after conjunction with the Sun.

It is a pleasure to record that Mr Burnham's careful observations of this comet have earned him a place on the staff of the Lowell Observatory, and that he discovered a second comet early in 1958.

(*Observations* 1957 *October* 2 *to October* 25)

1957 g, periodic comet Harrington (1) 1952 II, was recovered (after some unsuccessful searches) by Miss Roemer with the 40-inch reflector at Flagstaff on November 18. It was then a 20th magnitude object close to the position predicted by Kordylewski (*UAIC* 1608). Photographs were also taken on November 21 and December 12, just before conjunction with the Sun. Perihelion passage is in 1958 August, and the comet should again be observable at that time.

The question of the identity of this comet with P/Wolf (2) is still being discussed, but Kamienski has now expressed an opinion in favour of the identity.

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Basing his views on Kordylewski's work, which he has directed, Kamienski considers that the probability of the identity is as high as 0·85.
(*Observations* 1957 *November* 18 *to end of year, continuing*)

Unsuccessful searches were made during the year for Comets P/Schwassmann-Wachmann (3) (Lick), P/d'Arrest (Lick, Flagstaff), and 1955 b Abell, P/Olbers, P/Harrington-Wilson (Flagstaff).

The numerical designation of comets (in order of perihelion passage) has been extended by the I.A.U. Bureau (*UAIC* 1633). The list that follows continues that given in *M.N.*, **117**, 343, 1957. The perihelion dates (*T*) are from orbits noted in these annual reports.

Comet	*T*	Name	Year and letter
1954 I	Jan. 18·9	Harrington	1954 c
II	Jan. 24·7	Pajdušáková	1953 h
III	Feb. 5·1	P/Honda–Mrkos–Pajdušáková	1954 a
IV	Feb. 11·8	P/Van Biesbroeck	1954 i
V	Mar. 24·3	Abell	1955 b
VI	Mar. 27·6	P/Reinmuth (2)	1953 d
VII	May 22·9	P/Pons-Brooks	1953 c
VIII	June 1·9	Vozárová	1954 f
IX	July 2·5	P/Encke	1953 f
X	July 7·3	Abell	1953 g
XI	Aug. 13·5	P/Wirtanen	1954 j
XII	Aug. 29·7	Kresák–Peltier	1954 d
XIII	Dec. 18·2	P/Harrington–Abell	1955 a

The table giving the elements of cometary orbits is arranged as in previous reports. Comets are listed in order of perihelion date, which is normally given in U.T.; the symbol *E* indicates that the computer has used Ephemeris Time. A periodic comet is denoted by the symbol P/, and predicted elements by *p* after the perihelion date. Notes on each comet follow the table.

Additional Notes

Individual Comets

P/Halley. M. Kamienski, *Acta Astr.* **7**.

P/Wolf (1). M. Kamienski, *ibid*; further papers on these two comets are in course of publication.

P/Neujmin (2). E. A. Mitrofanova has computed perturbations from 1916 back to 1903 and has found no close approach to Jupiter in this period.

P/Encke. S. Y. Luchich. *Bull. Inst. Theor. Astr.* (*Leningrad*) (in press). A study of the 1931, 1934 and 1937 apparitions.

P/Kopff. F. Kepinski, *Acta Astr.* **7**, part 4, 1957.

1919 V, Metcalf–Borrelly. A. Przybylski has investigated the original orbit, and finds it to be elliptical. (*Acta Astr.*, **7**, part 4, 1957.)

P/Pons–Winnecke. V. Guth, *Contr. Skalnaté Pleso* **2**, 38, 1957. The secular perturbations of the orbit of Comet Pons-Winnecke.

P/Tuttle–Giacobini–Kresák. L. Kresák, *Contr. Skalnaté Pleso* **2**, 57, 1957.

P/Oterma. Miss L. Oterma, *Ann. Univ. Turku*, A, 27, 1957, and *Astr.-Opt. Inst. Turku*, Inf. No. 17. After a close approach to Jupiter in 1963, the comet will cease to be visible at each opposition, *q* being increased to 5·35 and *P* to 19·2 years.

1955 f, Bakharev–Macfarlane–Krienke. A. Bakharev describes photometric observations in *Bull. Stalinabad Obs.*, 19, 1957 and *Astr. Circ. U.S.S.R.*, No. 179, 1957.

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1956 h, Arend–Roland. Observations and physical studies made in the U.S.S.R., *Astr. Circ. U.S.S.R.* Nos. 180–185, 1957.

1957 d, Mrkos. *Ibid*, Nos. 184–186, 1957. Many other papers on these last two comets have been published.

General

J. G. Tyror has investigated the distribution of the perihelia of long-period comets (*M.N.*, **117**, 370, 1957); this has been criticized by Vsessviatsky (*Observatory*, **77**, 206, 1957) who, with O. I. Mescherryakova–Babich, has studied the distribution of the elements with reference to the eruption theory of the origin of comets (*Astr. Journ. U.S.S.R.*, **34**, 4, 1957). K. A. Steins discusses the influence of perturbations by stars and by Jupiter on the distribution of cometary orbits in a series of papers in *Astr. Journ. U.S.S.R.*, vols. **32**, **34** and **35**; while in vol. **34** will also be found a paper by P. G. Dukhnovsky on the change of cometary orbits caused by planetary perturbations, regarded as a case of the restricted three-body problem. T. V. Vadopyanova has published a fifth supplement to Vsessviatsky's Catalogue of Absolute Magnitudes of Comets.

The work of the Czechoslovak astronomers is well represented in vol. **8** of *Bull. Astr. Inst. Czech.*, in which a number of papers of theoretical interest by Hruška, Kresák and Vanýsek appear. Kresák also discusses the distribution of the orbits of comets with small perihelion distances in *Contr. Skalnaté Pleso* **2**, 19, 1957.

J. G. PORTER

THE PRESIDENT'S ADDRESS ON THE AWARD OF THE GOLD MEDAL TO PROFESSOR ANDRÉ DANJON

Dr W. H. Steavenson

The Gold Medal of the Society has been awarded by the Council to Professor André Danjon for his contributions to astronomical photometry, to fundamental astronomy and to the design of astronomical instruments.

It is impossible to read through a mere list of Danjon's published papers without being impressed by his remarkable versatility. In fact his investigations have ranged over so wide a field that it is not possible to describe them adequately in a short statement. But the Council has selected three aspects of his work to form the grounds of this award of the Gold Medal. Two of these are concerned with his skill in the design and use of astronomical instruments of great precision, and it will be convenient to take them together.

In the earlier part of his observational career, from 1919 to 1945, our medallist worked at the Strasbourg Observatory, of which he was Director during the last fifteen years of this period. The principal instrument at the Observatory is a 49 cm refractor of fine quality, and for sixteen years Danjon had the sole charge of it. He used this instrument for a great variety of purposes, but we are here mainly concerned with those lines of research which involved the use of special auxiliary apparatus of his own design.

The many problems of visual photometry seem to have attracted him from an early stage, and he devised several new types of photometer, with a view to eliminating some of the inherent defects of those hitherto employed; and he also gave special attention to certain physiological factors known to contribute to the errors of the estimates. In several of his instruments he adopted the principle of superposition of the fields containing the comparison star and the object under observation, thus avoiding some of the errors due to the common practice of using an artificial comparison star.

He also developed a so-called " cat's eye " photometer, which he found applicable to a variety of photometric researches. With it he made a series of observations of Algol, which yielded results comparable with those obtained by photo-electric means. With the same instrument he made the first complete photometric study of Earthlight on the Moon, comparing the brightness of certain regions with that of the sunlit part of the disk, which he then, with another double-image photometer, compared with the Sun itself. The resulting measures gave him a light-curve of the Earth in relation to phase-angle, together with a mean value for the Earth's albedo, with seasonal variations. Finally he obtained the colour-index of our planet, which proved to be unexpectedly small, showing that the Earth is much less yellow than the other planets, appearing positively blue in comparison with Venus.

He applied his cat's eye photometer to studies of the totally eclipsed Moon, and the distribution of light within the Earth's shadow; while, with another photometer, he made measures of the light of Mercury and Venus, comparing these planets directly with the Sun, reduced optically to a point source. The

light-curve for Mercury was found to resemble that of the Moon, while for Venus the results were similar to those deduced for the Earth.

Finally, he used a specially designed double-image photometer for determining the magnitude of the companion of Sirius.

Another line of work pursued by Danjon with the Strasbourg telescope was the accurate measurement of double stars. For this purpose he designed a special double-image interference micrometer. In this instrument he used square apertures of variable size, a Babinet compensator producing a difference of half a wavelength in the two optical paths. Danjon found that very precise measures of distance were obtainable with this apparatus; and he further developed a new method of computing the orbits of binaries by combining these measures with the position-angles obtained by previous observers. This micrometer, used simply as an interferometer, was found equally useful in measuring very close pairs, and the diameters of such small objects as the satellites of Jupiter. In this work the relatively great amount of light available in this particular instrument was found to be a special advantage.

From the time of his appointment as Director of the Strasbourg Observatory, Danjon began to pay an increasing amount of attention to meridian astronomy, and especially to the problems posed by the inherent optical and mechanical defects of the instruments previously in use. The result of much thought on this subject was the design and construction, in 1934, of a reflecting transit instrument. Briefly stated, this consisted of a small transit, made compact by optical folding. In front of the central part of the 6 cm objective was placed a Wollaston prism, with its reflecting surface in the plane of the meridian. Two images of a star are then seen, one direct and the other reflected, moving apparently in opposite directions and coalescing at the instant of meridian passage. An impersonal micrometer of conventional design is used in the observations. A firmly fixed collimator, used in conjunction with a mercury trough, serves to check the constancy of the optical plane of the prism. Finally, a special eyepiece for nadir observations was designed by Danjon.

The accuracy controls of the whole instrument are purely optical and include a device for determining and allowing for the effects of slight comatic distortions of the axial image of the star under observation. Apart from the micrometers, none of the mechanical parts needs to be constructed with high precision; and the instrumental constants are determined at the moment of each transit.

With this instrument Danjon found that by a single night's observation he could determine time within 6 or 7 milliseconds. This is a remarkable and suggestive result, when it is remembered that the probable errors of the Right Ascensions of the FK3 catalogue, based on work with meridian instruments of conventional design, ranges up to 8 milliseconds.

From the reflecting transit Danjon next turned his attention to an instrument of the same family, the prismatic astrolabe. This is essentially an equal-altitude instrument, and its application is confined to stars which culminate at a limited zenith distance of 30°. This angle is determined by that of an equilateral prism, placed immediately in front of the objective. The form previously evolved by Claude and Driencourt had certain defects, and these Danjon proceded to eliminate by some ingenious modifications of the optical train. In addition, the instrument was provided with an impersonal micrometer, and there was a device for compensating certain optical effects due to the independent

action of the two halves of the objective. The whole instrument is of great compactness, and although its aperture, like that of the reflecting transit, is only six centimetres, it is capable of determining time with an accuracy comparable with that attainable with a bulky meridian instrument of the ordinary type.

Though a large part of the most outstanding work of our medallist has been, as we have seen, of a practical kind, he has by no means neglected the theoretical side of our science. Among other things, he has developed Laplace's method for the determination of orbits in two different ways; the method of fictitious positions and the method of variations. His *Astronomie Générale* (Astronomie Sphérique et Élements de Mécanique Céleste) published in 1952, is a most valuable contribution to fundamental astronomy, and there is no other book which covers the same ground. Since his organization of the Paris Conference on the Fundamental Constants of Astronomy, in 1950, he has made invaluable contributions, both theoretical and instrumental, to this subject, particularly in regard to the definition of Ephemeris Time and the determination of Universal Time.

He has spent much time in an investigation of the conditions for telescopes and domes, to obtain the best definition; and his work *Lunettes et Telescopes*, written in conjunction with A. Couder in 1935, is the best treatise on all matters relating to telescopes. A second edition of this invaluable work is now in preparation.

Since his appointment in 1945 as Director of the Paris Observatory, Danjon has played a very important part in some of the recent spectacular developments in French Astronomy. In particular he has been largely responsible for the successful prosecution of the plan for establishing a great observatory in Haute Provence, a project in which he has been personally concerned ever since its inception under General Ferrié in 1923. He is now President of the Commission Internationale des Poids et des Mésures, and his high standing in our science has further been recognised by his election as President of the International Astronomical Union.

I have tried to lay before you, however inadequately, the grounds selected by the Council for the award of the Society's Gold Medal. In doing this I have been forced to omit all reference to the many other astronomical activities of Professor Danjon, whose objects of observation have ranged from comets to total eclipses of the Sun, and from occultations to the surface features of Mars. But I should like to conclude by quoting some of his own words, partly because they illustrate his enthusiasm as a practical astronomer, and partly because they seem to accord so closely with the motto of our Society.

> " It is the bounden duty of astronomers to think as much about the future progress of Astronomy as about their own particular labours; and their activities should be ruled by the maxim that an observation well made will be found of use at some time or another, while an observation missed may leave a gap that can never afterwards be filled."

XUM

THE PRESIDENT'S ADDRESS ON THE AWARD OF THE EDDINGTON MEDAL TO DR HORACE W. BABCOCK

Dr W. H. Steavenson

The Eddington Medal has been awarded to Dr Horace W. Babcock for his work on the magnetic fields of early-type stars and of the Sun.

Babcock's work on the general magnetic field of the Sun was carried out in association with his father, H. D. Babcock, whom we are proud to number among our Associates. Their earlier work on this problem had shown that, in view of the minuteness of the quantities to be measured, special attention must be paid to the details of the apparatus. Accordingly, in 1952, the Babcocks assembled at the Hale Solar Laboratory a new apparatus embodying certain special features. These included (1) a superior new grating, blazed in the fifth order green, where the dispersion was 11 mm per angstrom and the resolving power 600 000; (2) an analyser consisting of an electro-optic crystal of ammonium dihydrogen phosphate, followed by a Nicol; (3) not one but two slits at the focal plane of the spectrograph, set on opposite sides of the line profile, where this is the steepest, the light from the slits being fed directly into a photomultiplier. This was a great improvement on the photographic method; and (4) a cathode-ray tube to give on its screen indications of magnetic intensity and polarity, such indications being continuously photographed. Babcock considers that the sensitivity of the equipment is of the order of 1 gauss.

With this apparatus it was possible to scan the Sun's disk in a series of about twenty strips in less than an hour, and thus to produce a complete picture of the magnetic conditions over the whole disk at the epoch of observation. The observations made it clear that the intensity of the Sun's general magnetic field was small, amounting at the most to only a few gauss.

From the magnetic field of the Sun to those of the stars must clearly be the next step forward, and it is this line of research that our medallist has made particularly his own.

The rapid axial rotation of many stars of early spectral type, with equatorial velocities of the order of 100 km/sec, has been known for many years from studies of Doppler line broadening. Comparison with the much slower rotation of the Sun (2 km/sec) suggested that the rapidly rotating stars might have correspondingly stronger magnetic fields, with intensities possibly as great as a few thousand gauss. But, in order to detect the comparatively small line shifts due to Zeeman polarization, it is necessary to examine lines that are sharp and not greatly affected by rotational broadening. The rotational axes of the stars are probably directed at random; therefore the small percentage of early-type stars with sharp spectral lines should include some that are in fact in rapid rotation, the axes being directed nearly towards the Earth.

The very nature of the investigation obviously demanded considerable modification of the apparatus, as compared with that used for the Sun. Very high dispersion in the grating was ruled out by the faintness of the light source and the necessary narrowness of the slit; and there were some special complications to be overcome or allowed for, such as instrumental polarization in the coudé system of the great reflectors employed.

A special form of analyser was developed, consisting of a quarter-wave plate in contact with a calcite crystal. This analyser has the desirable features that the two oppositely polarized spectra are recorded simultaneously, and that none of the light is wasted. With this apparatus, used on the 200-inch telescope, a double spectrum of a seventh magnitude Ao star, at a dispersion of 4·5 A/mm, can be obtained under average conditions in about two hours. The probable error of measurement is naturally far greater than in solar work, amounting to a few hundred gauss. However the strength of many of the magnetic fields involved is fortunately far greater, as had been anticipated, amounting to several kilogauss.

Of the stars so far examined, several have exhibited no detectable magnetic field, but among others field strengths of up to 10 500 gauss have been found. In quite a large proportion of these, the strength of the field is markedly variable over a considerable range, amounting in one instance to no less than 13 000 gauss; and in several cases an actual reversal of polarity has been noted.

It is in the outstanding spectrum variables that periodic magnetic variations of the greatest amplitude have been found. Four giant M-type stars, having peculiar spectra with emission features, show in their absorption lines evidence of a magnetic field, and in one of these the strength of the field fluctuates in intervals of a few weeks, sometimes reversing its polarity.

In a recent Supplement to the *Ap. J.*, Babcock summarizes the results of 11 years' work on 216 stars with lines narrow enough to permit magnetic measurements.

The observational programme has involved a sampling of stars in various parts of the H–R diagram. Of the stars showing observable magnetic fields, one is a sub-dwarf, two are of type S, three are M-type giants, seven are metallic-line stars, and 66 are A-type stars with sharp or ultra-sharp lines. While very strong magnetic fields of one outstanding polarity are essentially limited to the stars of type A, there is much support for the view that significant fields, often of mixed polarity, occur in the atmospheres of virtually all stars.

All stellar magnetic fields sufficiently observed are found to be variable, and the great majority vary irregularly, proving that large-scale intrinsic hydromagnetic fluctuations occur at the surfaces of these stars. Of the A-type stars observed, five are regular magnetic variables with periods near one week, very large and nearly uniform magnetic amplitude, and nearly symmetrical reversal of polarity; 22 are irregular magnetic variables, showing reversal of polarity; and 15 are irregular magnetic variables always showing the same polarity.

These are but a few of the results so far obtained by our medallist; but they will be sufficient to make it clear that we are here presented with pioneer work of a high order, which must be accounted as of the greatest significance to the astrophysicist. You will agree that it amply justifies the award of the Eddington Medal; and we may surely feel confident that it would have gladdened the heart of the man whose name and work the medal commemorates.

We are sorry that Dr Babcock is not able to be with us today; but Mr Munsing, the cultural affairs officer of the United States Embassy, has kindly come to receive the medal on his behalf.

Mr Munsing, I ask you to convey to Dr Babcock, with this medal, our congratulations on the advances he has made in an important field of astrophysical research, and our cordial good wishes for still further successes in the years to come.

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